# User Manual

## A³ Wireless Sensor Network

Doc #: SWRFIO02, Version 2.4

SpinWave™ Systems
Energy Savings Made Affordable

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# Chapter 1

# Introduction

- The Spinwave $A^3$ Product Line
- Wireless Sensors/Transceivers
- Mesh Repeaters/Routers
- Receivers
- Deployment Tools

## The Spinwave A$^3$ Product Line

The Spinwave A$^3$ product line is based on Spinwave's extension of the IEEE 802.15.4 specification for ultra-reliable operation. Wireless sensors transmit sensor data to the Spinwave Receivers which pass data to a Building Management System (BMS) interface.

Spinwave's product line provides a complete solution consisting of:

- A family of wireless sensors and transceivers. Wireless sensors have on-board sensing elements to measure temperature and relative humidity. Wireless transceivers interface to external thermistors, RTDs, DC voltage sources, dry contacts or meter pulse outputs.
- Wireless repeaters/routers, significantly extending the wireless network's range.
- Receiver/Interface modules providing direct connectivity to a broad range of automation systems, embedded devices and PCs
- A laptop-resident binding and commissioning tool specifically designed for installers to deploy, commission, document and maintain the wireless network in a fast, efficient manner.

## Product Benefits

- Eliminates wire and conduit and reduces installation labor costs
- Preserves original building architecture
- Easily allows for expansion of a current system or changing floor plans
- Economical means of obtaining greater building environment control through the use of more sensors
- Minimizes bid risk
- Reduces installation time and minimizes project dependencies and delays
- Opens new service opportunities and markets, e.g. continuous commissioning, monitoring and verification

# Wireless Sensors and Transceivers (SWS-xxx)

**Wireless Sensors and Transceivers** are available in a variety of form factors (e.g. zone, outdoor) and for measuring different variables, like temperature, relative humidity, voltage, dry contact, and meter pulses.

List of available sensors and transceivers:

| Part Number | Description |
|---|---|
| | Wireless Sensors/Transceivers – Temperature |
| SWS-T | Wireless temperature sensor, on-board thermistor |
| SWS-TEXT | Wireless transceiver with external 10K, type III thermistor, 10' leads included |
| SWS-T-2EXT | Wireless transceiver with on-board thermistor and 2 external 10K, type III thermistors, 10' leads, and mounting magnets included |
| SWS-3TEXT | Wireless transceiver with 3 external external 10K type III thermistors, 10' leads, and mounting magnets included |
| SWS-2PT100 | Wireless 2xRTD (PT100, not included) transceiver |
| SWS-2PT100-N4BAT | Wireless 2xRTD (PT100, not included) transceiver in NEMA4X outdoor enclosure with battery holders |
| SWS-2PT100-N4PSI | Wireless 2xRTD (PT100, not included) transceiver in NEMA4X outdoor enclosure with 120VAC/9VDC supply |
| | Wireless Sensors/Transceivers – Relative Humidity |
| SWS-TRH | Wireless zone temperature & relative humidity sensor, 1.8% RH |
| SWS-TRH-2TEXT | Wireless transceiver with on-board temperature & relative humidity sensor (1.8% RH) and 2 external 10K, type III thermistors, 10' leads, and mounting magnets included |
| | Wireless Sensors – Analog Inputs |
| SWS-3AI | Wireless analog input module with three 0-5VDC inputs |
| | Wireless Sensors – Digital Pulse Counter |
| SWS-DPC | Wireless Digital Pulse Counter |
| SWS-DPC-N4BAT | Wireless Digital Pulse Counter in NEMA4X fiberglass enclosure with battery holders |
| SWS-DPC-N4PSI | Wireless Digital Pulse Counter/Repeater in NEMA4X fiberglass enclosure with internal 9VDC power supply |
| SWS-DPC-N4BAT-IOR-D | Configured kit: SWS-DPC-N4BAT, SWRF-IOR-D, SWPSUP-24 |
| | Wireless Sensors – Digital Input |
| SWS-DI | Wireless Digital Input (dry contact) |
| SWS-DI-N4BAT | Wireless Digital Input in NEMA4X fiberglass enclosure with battery holders |
| SWS-DI-N4PSI | Wireless Input/Repeater in NEMA4X fiberglass enclosure with internal 9VDC power supply |

Sophisticated power management results in long battery life - 2 to 8 years, depending on transmission intervals.

| Sensor Transmission Interval | Battery Life |
|---|---|
| 10 sec | 2 years |
| 21 sec | 3 years |
| 42 sec | 5 years |
| 84 sec | 8 years |

Sensors are usually battery powered; a line-voltage power option is available for difficult to service locations. When a sensor detects the presence of a power supply, it automatically functions as a **repeater/router**.

## Mesh Repeaters/Routers (SWRP)

In addition to being able to permeate most building materials, **Mesh Repeaters / Routers** significantly extend the range and node count of wireless sensor networks.

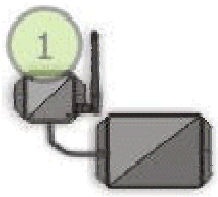
Repeaters/Routers are compatible with all receiver options and provide alternate wireless communication paths from Sensors to other Repeaters to RF Receiver Modules thus improving the network's ability to cope with obstacles.

The wireless network automatically "heals" and reconfigures itself if a communication path is obstructed.

Repeaters/Routers feature high-power radios (20dBm) requiring an external 5VDC power supply (e.g. SWPSUP-2).

# Receivers (SWRF-xxx)

## BMS Protocol Gateway



The **BMS Protocol Gateway** easily connects Spinwave's wireless sensors to open-protocol systems, BMS, PLCs, SCADA, and monitoring software.

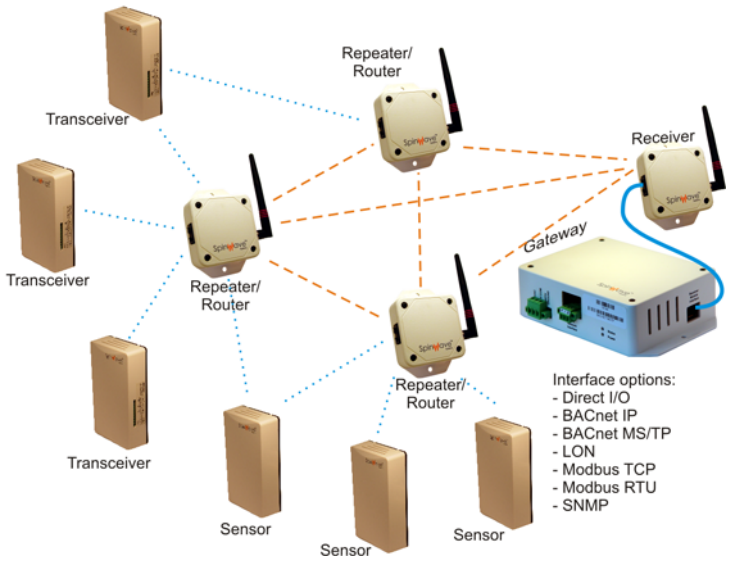
Up to 50 separate wireless devices (sensors and/or repeaters) are supported per Protocol Interface.

Available versions are:

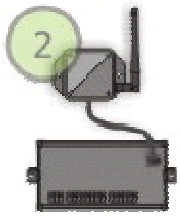
**SWRF-BACNET-IP:** Receiver/BACnet IP gateway
**SWRF-BACNET-MSTP:** Receiver/BACnet MS/TP gateway
**SWRF-MODBUS-TCP:** Receiver/Modbus TCP gateway
**SWRF-MODBUS-RTU:** Receiver/Modbus RTU gateway
**SWRF-LON:** Receiver/LON gateway
**SWRF-SNMP:** Receiver/SNMP gateway

Sensor data and device health status are mapped to network variables and are presented to the automation/monitoring system as native BACnet objects, LON SNVTs or Modbus registers.

Multiple BMS Protocol Gateways can exist in proximity of each other (e.g. one per floor, receiving data from multiple wireless sensors).



## BMS I/O Interface

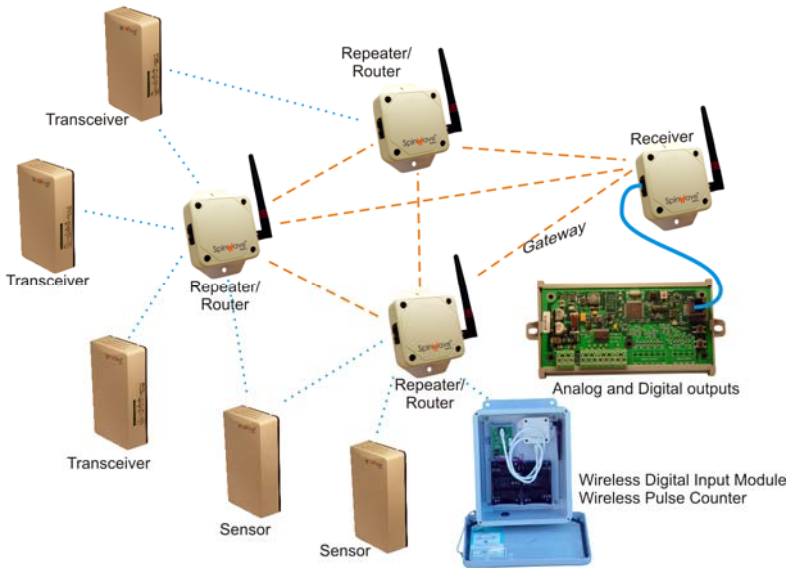


The **BMS I/O Interface** consists of a Receiver Module and a remote Direct I/O Interface and is ideal for applications requiring only a few sensors or for situations where the Building Management System does not provide open protocol connectivity. Available versions are:

**SWRF-IOR:** BMS I/O interface with 4 analog outputs, 4 digital outputs and one status output.

**SWRF-IOR-D:** BMS I/O interface with 4 digital outputs and one status output.

Analog sensor values (temperature, relative humidity, voltage) can be mapped to analog outputs on the BMS I/O interface and sensor values are available as 0-5VDC or 0-10VDC values. Mapping of multiple sensors (e.g. temperature sensors) to the same analog output will automatically **average** those values.
Digital pulse counters (SWS-DPC) and digital input modules (SWS-DI) can be assigned to digital outputs on the BMS I/O Interface. Mapping digital pulse counters to a digital output will replicate meter pulses wirelessly.
Mapping of multiple digital input values (SWS-DI) to the same digital output will automatically **OR** those values.
A pre-assigned digital status output indicates sensor network trouble (low battery or sensor communication time-out). The digital output can be configured as a pulse or latched signal.
To make wireless sensor readings available to a Building Management System, I/O Interface outputs are simply wired to building automation controller inputs.



# Deployment Tools

## NQ – Commissioning and Maintenance Software (SWNQ)

**NQ** PC software is a commissioning and maintenance tool allowing user to:

- Connect a PC via USB cable (SWNQCBL) to a sensor network
- Conduct a site survey
- Import building floor plans
- Automatically discover wireless network devices
- Configure sensors and interfaces
- Graphically map sensor values to interface objects
- Monitor and verify sensor data and network status
- Document system configurations

NQ requires Microsoft's .NET V3.5 framework and FTDI's virtual serial port (USB driver for SWNQCBL) to be installed.

NQ is compatible with Windows XP, Vista, and Windows 7. The NQ software and the required FTDI USB driver can be downloaded from Spinwave Systems' support web site.

The USB Configuration Cable (SWNQCBL) can be connected to the **Console Port** of any wireless sensor, SWRF-IOR or Protocol Gateway.

Open field range between devices:

| Device A | Device B | Max. Range |
|---|---|---|
| SWS-T, SWS-TEXT, SWS-3TEXT, SWS-T-2EXT, SWS-TRH, SWS-TRH-2TEXT, SWS-3AI | SWRP, SWRF-xxx | 1,000 feet |
| SWS-DPC, SWS-DI, SWS-2PT100 | SWRP, SWRF-xxx | 3,500 feet |
| SWRP | SWRP, SWRF-xxx | 3,500 feet |

# Chapter 2

# Planning

- Application Overview
- Open Protocol Interface
- Wireless I/O Replication

## Application Overview

Spinwave Systems' wireless mesh network has been designed specifically for the building automation and monitoring markets. Products are easy to install, integrate, commission and maintain.

"No wires" means that sensors can be easily mounted and relocated as system requirements change or floor plans evolve. There are no wires or conduit to deal with thus dramatically reducing installation or reconfiguration time and cost.

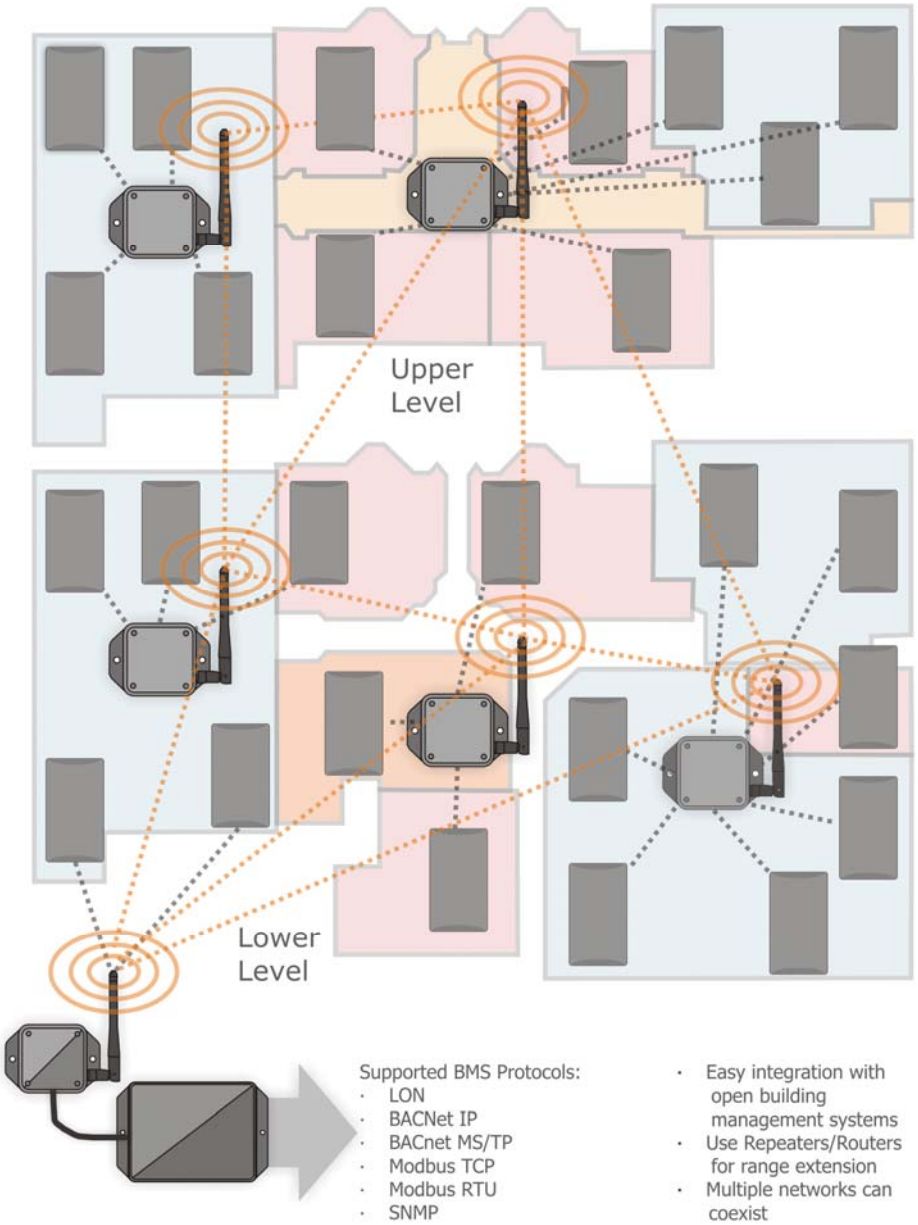
Applications for wireless sensor networks include:

- Retrofit projects
- High installation cost locations
- Unique, difficult to wire installations
- Fast track projects
- Improved zone control
- Energy services
- Demand/Response
- Continuous commissioning
- Condition monitoring
- Data Center Monitoring
- Warehouse Monitoring
- Green buildings
- Utility Metering

## Open Protocol Interface

Multiple wireless sensors can be interfaced with Building Management systems through Spinwave's BMS Protocol Interface. Protocol options include: BACnet, LON, Modbus and SNMP.

1 BMS Integration via Open Protocol Interface



The BMS Protocol interface is typically used in applications requiring multiple wireless sensors. Sensor data is transmitted to the receiver radio. The gateway receives sensor data from the radio and makes it available as Modbus registers, LON snvts or BACnet objects.

Each sensor transmits one or more measurement values and health status, indicating low battery condition and/or communication timeout.

Repeater/routers, using high-power radios, are used to transmit over longer distances or through floors/ceilings and multiple walls. Repeaters also provide alternate wireless communication paths and strengthen the overall network reliability.

## Example: Data Center Monitoring

Rapidly escalating connectivity requirements, explosion of cloud computing, and an increasing emphasis on data mining are driving a major expansion of data center capacity.

Monitoring data center environments is becoming more important as modern equipment produces very concentrated heat loads.

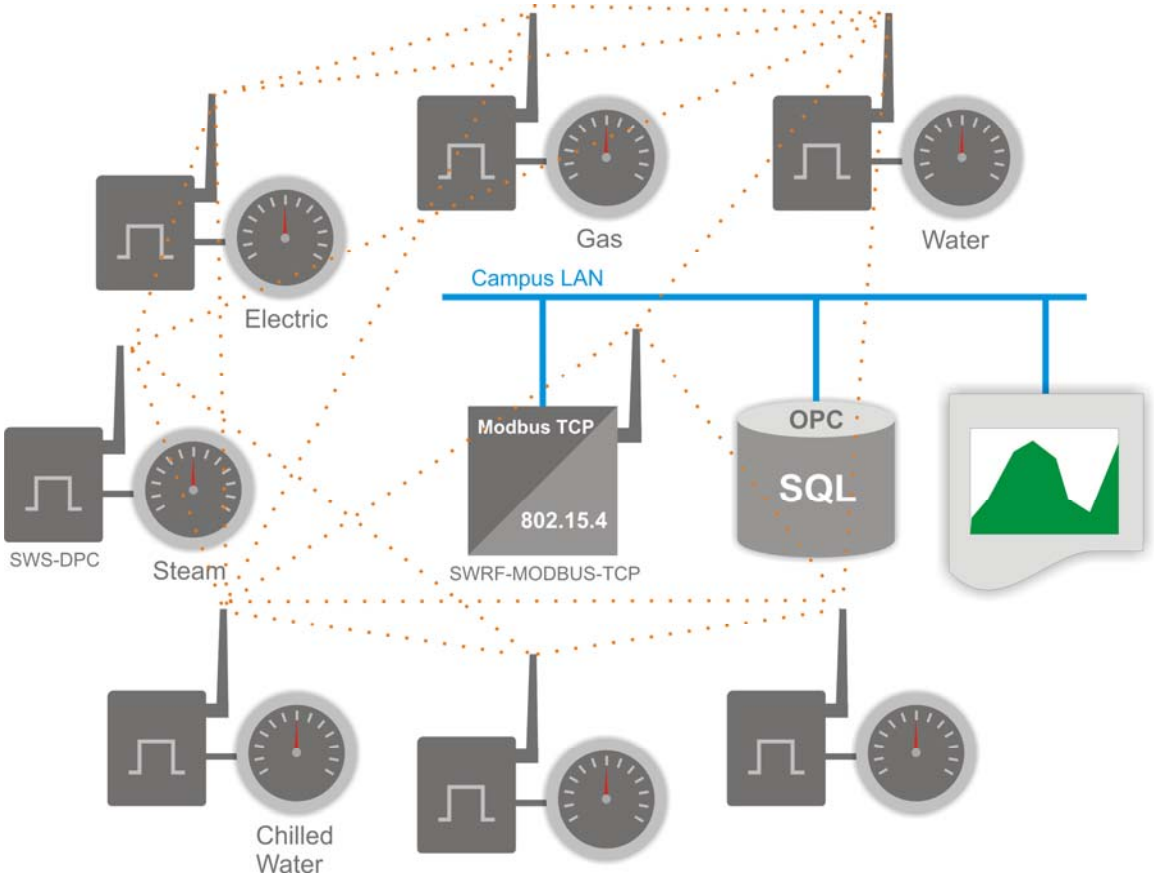
Spinwave Systems' wireless sensors enable precise air flow management and help eliminate physical threats to maximize energy efficiency and equipment uptime.

Spinwave's wireless sensors are available with on-board and external sensing elements (up to three) and can be installed easily and are ready to be interfaced to any building automation system, data center monitoring application or network management tool.

Sensors are available for measuring up to 4 independent variables (temperature, relative humidity, analog input, dry contact). A single receiver/gateway can receive up to 200 separate data points. Multiple gateways can co-exist within one location for projects requiring several hundred sensors.

## Example: Campus-wide Utility Monitoring

For those who manage campus properties, benchmarking and comparing utility usage across all buildings presents a continual challenge. Yet, this data is essential to effective facilities management, especially at a time when energy consumption is of primary concern to many facility owners.
Establishing norms for water, gas, and electricity use during various times of the year makes it easier to implement a realistic conservation program.




Spinwave's wireless pulse counters (SWS-DPC) connect to the pulse output of existing gas, water or electric meters and transmit meter data to a receiver/gateway. Demand and consumption data is available via industry protocols, like Modbus, BACnet and LON.

Wireless pulse counters use high-power radios (line of site range: 3,500 feet) can be battery operated (e.g. for outdoor meters) or powered by a power supply. Line powered pulse counters automatically act as repeaters, making it possible to communicate over wide distances and through walls and ceilings.

## Wireless I/O Replication

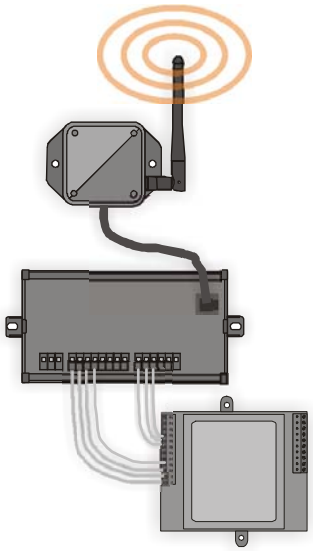
The BMS I/O Interfaces (SWRF-IOR and SWRF-IOR-D) are ideal for applications where a small number of wireless sensors have to be interfaced directly with controller or data gateway inputs.

Up to eight wireless sensors can be mapped to the interface's outputs (analog and digital). The BMS I/O Interface is typically mounted in the same enclosure as the building controller or data gateway it interfaces with. The remote RF Receiver can be placed outside of the enclosure for best RF conditions.

The RF range can be easily extended by placing Repeaters/Routers in strategic locations.

Multiple wireless networks can coexist by assigning them different PAN IDs (aka Network IDs).

2 BMS Integration via Direct I/O Interface

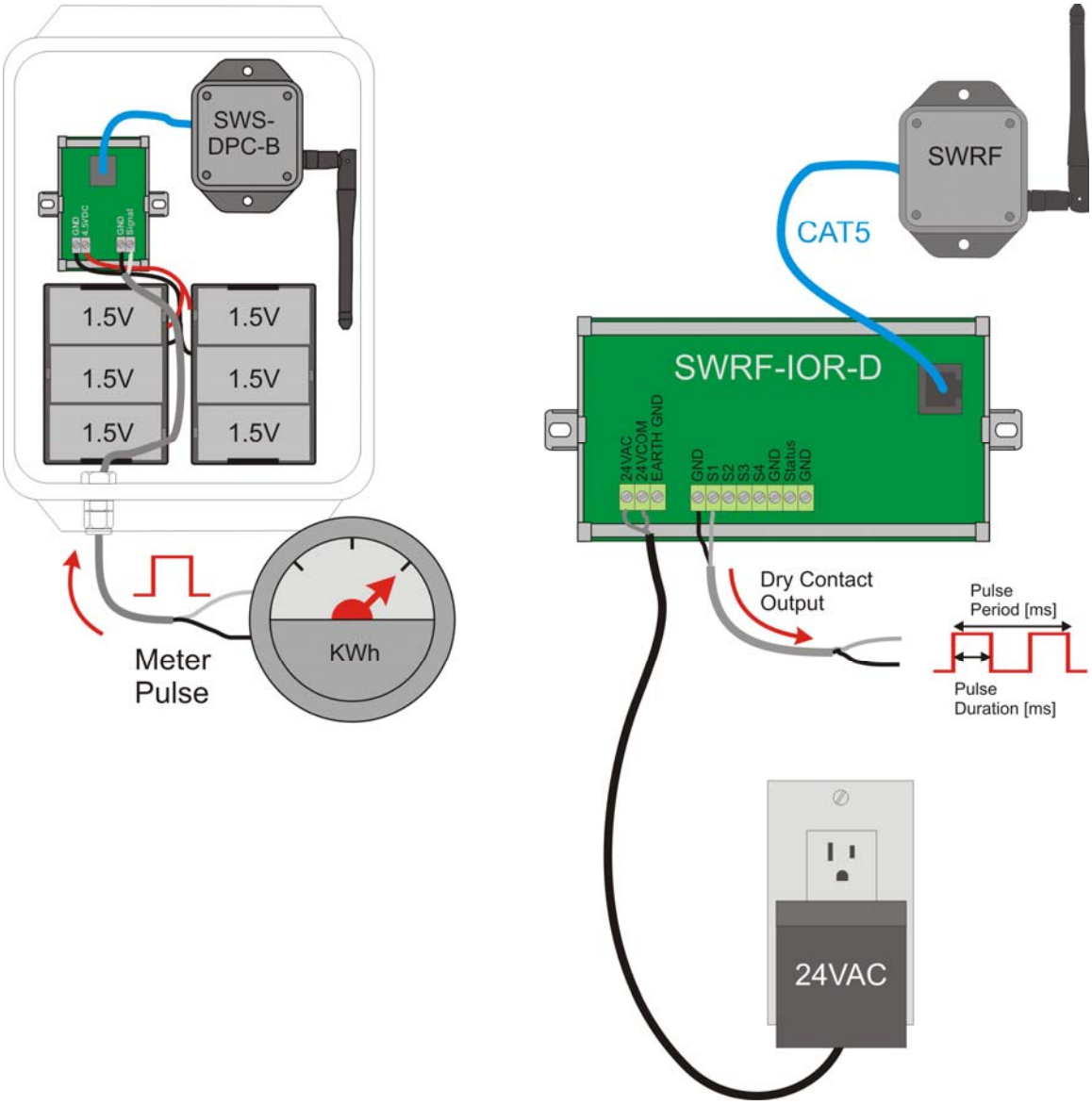


- Easy integration with proprietary building management systems
- Connects to BMS Controller inputs
- Use Repeaters/Routers for range extension
- Multiple networks can coexist

**Typical applications include:**

- Wireless load verification for demand/response projects and data gateway integration.
- Wireless parking lot lighting control.
- Wireless pump control.
- Wireless utility meter reading.
- Zone temperature monitoring for VAV control.

**Example: Wireless Meter Reading**




The system consists of one or more (up to 4) wireless pulse counters (SWS-DPC) in an outdoor enclosure and a receiver I/O interface (SWRF-IOR-D). Meter pulses are collected by the wireless pulse counter and transmitted to the receiver module. The I/O interface re-generates the meter pulses at its digital outputs. The maximum frequency (f = 1/Pulse_Period) and Pulse Duration of the re-generated pulse can be configured using NQ software. Digital outputs are wired to a controller or data gateway for remote access of consumption and demand. The Status output indicates low-battery or communication timeout (>45 minutes) and can be used as an alarm.

All meters with a “dry contact” pulse output (<90 pulses/sec.) are supported. The SWS-DPC can be battery powered or powered by a 9VDC power supply. When powered by 9VDC, the SWS-DPC will also function as a repeater.

The SWS-DPC uses a high-power radio with an open field range of up to 3,500 feet. Optional repeaters or line powered pulse counters can be used to extend RF range even further.

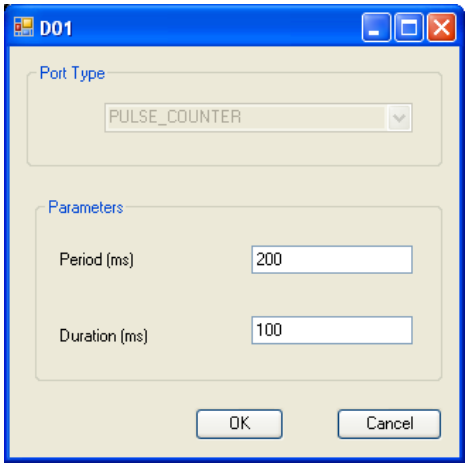
For consumption metering (KWh) set the sensor properties to:

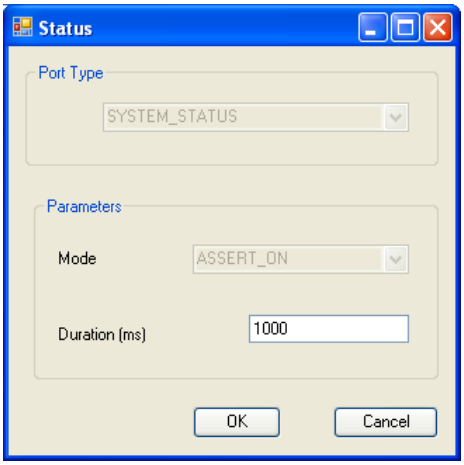
| Sensor Property | Value |
|---|---|
| Interval | >= 84 seconds |
| Delta PC | 1 |

For near real-time demand tracking (KW) set the sensor properties to:

| Sensor Property | Value |
|---|---|
| Interval | 10 seconds |
| Delta PC | 1 |

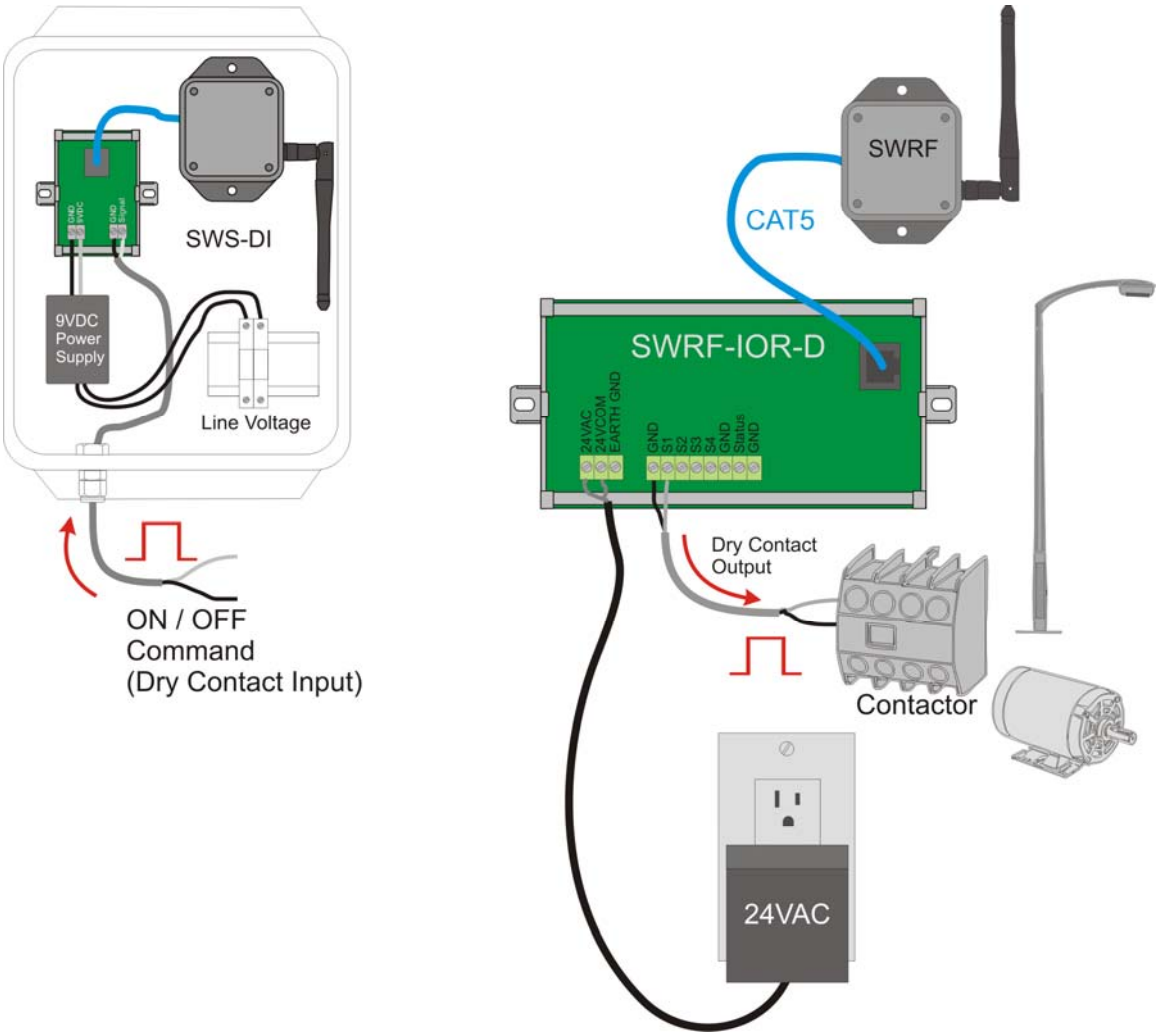
For most meters the following output settings will yield good results:




This will work for meters that produce up to 5 pulses per second (pulse_period = 200 ms, pulse_duration = 100 ms).

**Example: Wireless Lighting or Pump Control**

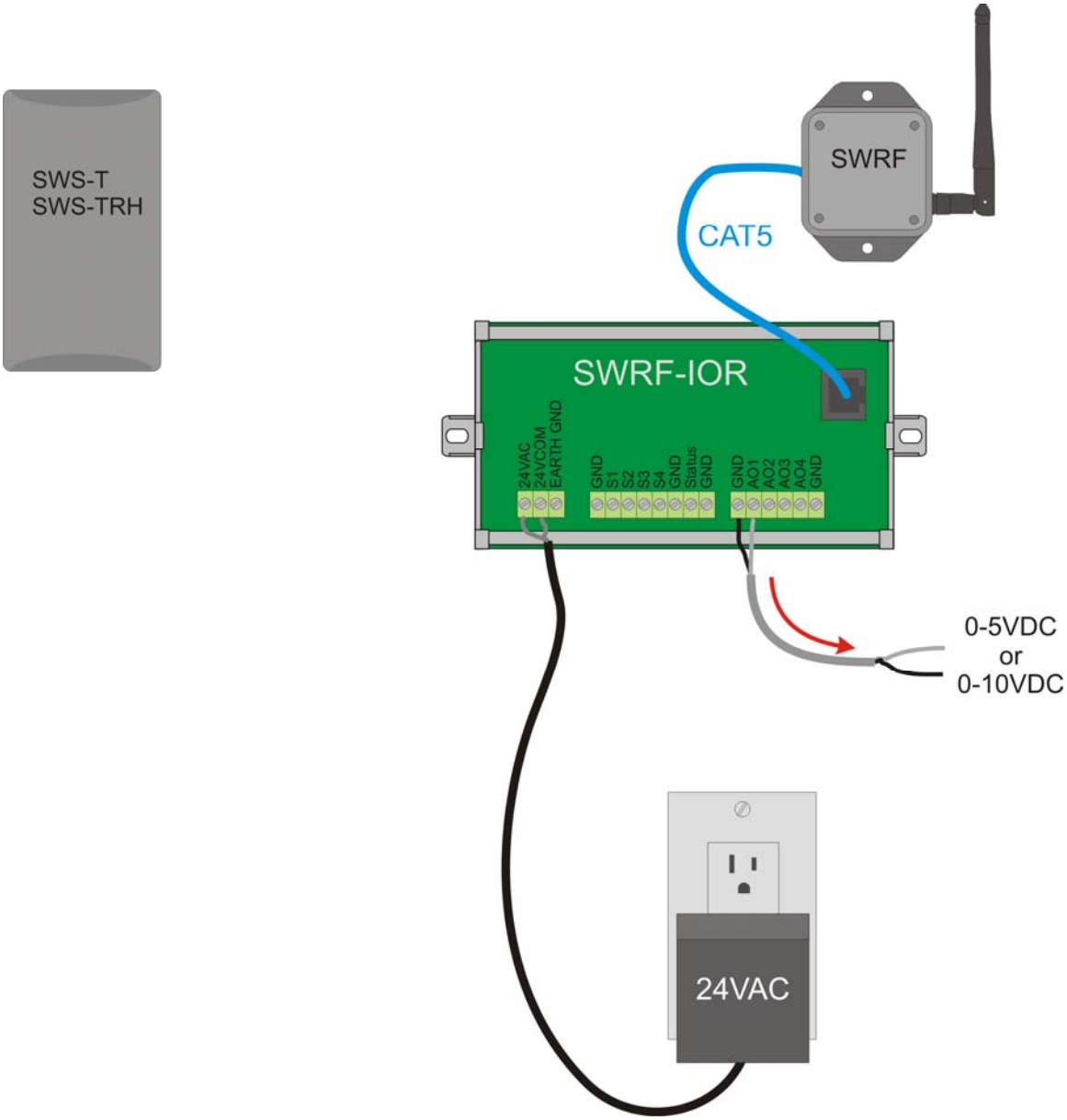



The system consists of one or more wireless digital input module (SWS-DI) and one or more receiver I/O interfaces (SWRF-IOR-D). The SWS-DI senses the status of a dry contact (e.g. from a lighting panel or pump controller) and transmits the value (ON or OFF) to the receiver module. The I/O module "mirrors" the dry contact status at its digital outputs. A contactor, controlled by the digital output, switches the electrical load (e.g. parking lot light, pump motor) ON or OFF.

It is possible to map multiple SWS-DI to the same digital output on the SWRF-IOR-D. In this can the dry contact signals are OR'd (the dry contact output closes if one or more of the dry contact inputs close).

The SWS-DI uses a high-power radio with an open field range of up to 3,500 feet and, because it is powered by a 9VDC power supply, also acts as a repeater. Additional repeaters can be used to extend RF range even further.

## Example: Wireless Zone Temperature Sensing for VAV Control




The system consists of one or more (up to 8) temperature sensors (e.g. SWS-T) and a receiver I/O interface (SWRF-IOR).

Temperature sensors are placed in occupied spaces and transmit zone values to the receiver I/O interface. The I/O module makes temperature (or relative humidity) values available as 0-5VDC or 0-10VDC analog output values. Analog outputs are wired to VAV controller inputs.
If more than one temperature sensor is mapped to the same analog output, the temperature values are automatically averaged (e.g. for zone average).

Optional repeaters can be used to extend RF range.

# Chapter 3

# Installation

- General Guidelines
- Installing NQ Configuration SW
- SWSRF-IOR: BMS I/O Interface with Remote RF Receiver Module
- SWRF-LON, SWRF-BACNET, SWRF-MODBUS: BMS Protocol Interfaces
- Sensors and Transceivers
- System Start-up Sequence

## General Guidelines

BMS Interfaces can be powered by an external 24 VAC or 12-24VDC source. In case of 24VAC, the unit should receive power from its own independent, 24 VAC +/- 20%, 50 or 60 Hz circuit.

For reliable operation, follow these input wiring guidelines:

- Never run wires across the surface of the printed circuit board.
- Use shielded input wire. Do not use the shield as the signal return wire.
- Terminate the shield of the input wires at one end of the run only.
- Do not run your I/O interface wiring in the same conduit with AC power.

The earth ground wire to the DDC I/O Interface should not exceed 12 inches (30 cm, 18 gauge minimum) in length and it must be connected to a good earth ground. This will protect the equipment from transients and other power surges. Do NOT connect earth ground to signal ground. We cannot guarantee that the system will operate as documented without a properly grounded installation.

Do not use this product in any safety related applications where human life may be affected.

Sensors, Repeaters and Receivers should NOT be installed in the following areas:

- Inside metal enclosure/panel or behind wire mesh
- Inside or immediately next to elevator shaft/elevator banks

Otherwise, transmission distance and performance will be drastically reduced.

To avoid damaging electronic components due to electrostatic discharge, always ground yourself before touching any circuit boards or internal components of Spinwave devices.

- Discharge yourself by touching metal first
- If possible, use a grounding strap or heel plate

Failure to observe this precaution can result in equipment damage.

## Installing NQ Configuration Software

NQ can be installed on PC with the Windows XP, Vista, Windows 7 (32-bit and 64-bit).

The software can be downloaded from Spinwave's support web site. This web site is password protected. You will receive your login information with your order.

Before installing NQ on your PC, check if Microsoft's .NET V3.5 framework is installed. If .NET V3.5 is not installed, click on the link to Microsoft's download page on the support web site.

Your PC uses the USB configuration cable (SWNQCBL) to communicate with the BMS Protocol Interface or Direct I/O interface. The USB cable requires a virtual COM port driver (simulating a serial COM port over USB). The download link for the USB driver (FTDI serial port driver) is located on the support web site. Install the FTDI USB driver before installing NQ.

You can install NQ from the support web site either as a web install or download a ZIP file.

Plug the USB cable (SWNQCBL) into your PC's USB port. You PC's operating system will detect a new USB device. Go to "Control Panel -> System -> Device Manager" and check the COM port number that was assigned to the cable.

After starting NQ, go to "Network Preferences" and select the COM port from the drop down list.

When starting NQ, the software will connect to Spinwave's support web site and check for newer versions.

## SWRF-IOR: BMS I/O Interface with Remote RF Receiver Module

The BMS I/O Interface is designed to be mounted close to the automation controller or data gateway it will interface with.

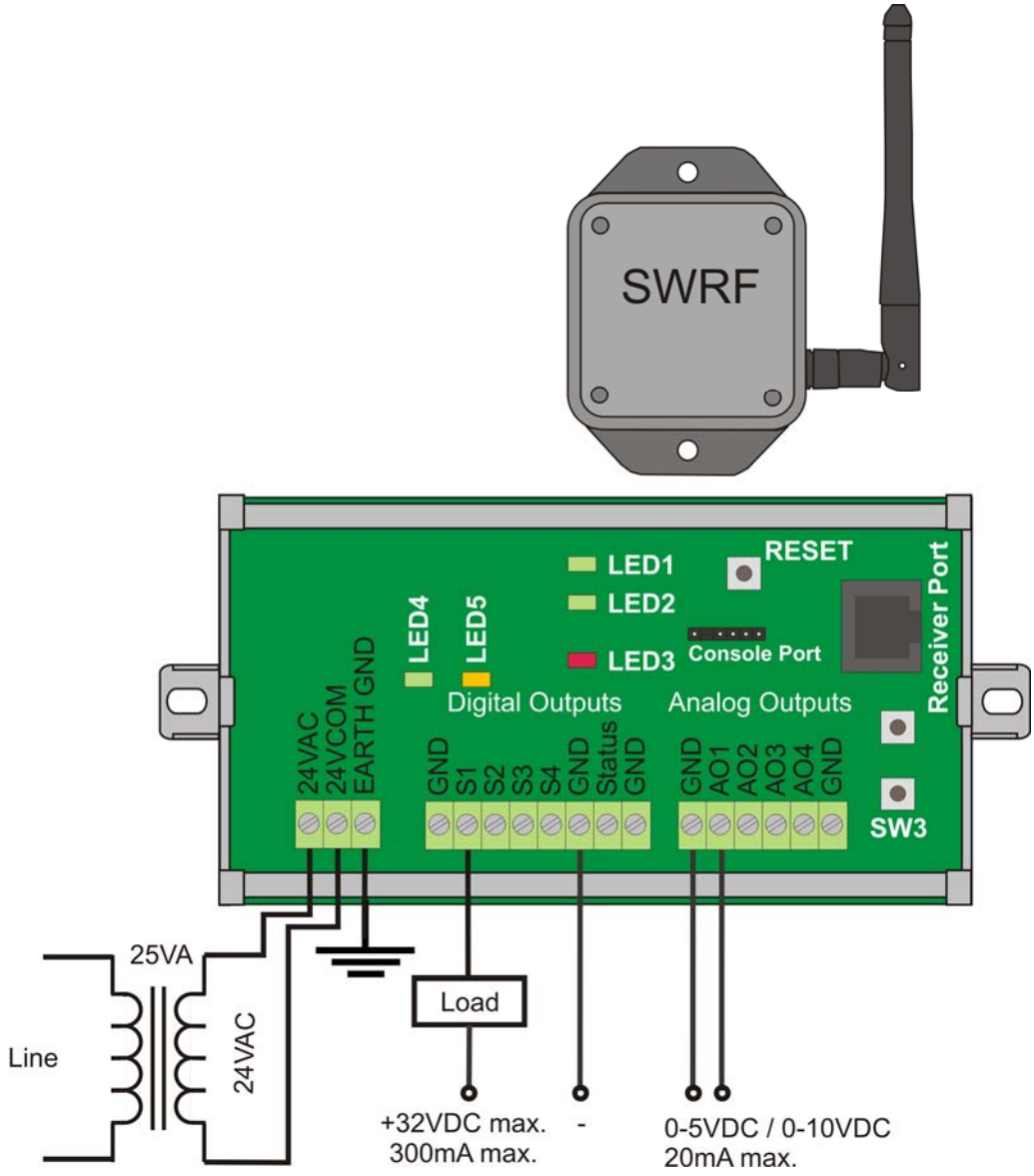
The BMS I/O Interface is intended for field installation within an enclosure. For best RF performance, the receiver radio should **NOT** be mounted inside a metal enclosure or behind a wire fence.

The receiver module is connected to the I/O interface using a standard CAT5 patch cable (Ethernet cable). The cable can be extended to up 30 feet. This allows to remotely mount the radio at locations with good RF properties.

The receiver antenna should always point up or down (vertical orientation).

The following diagram shows power connection, I/O terminal configuration and communication port locations of the BMS I/O Interface and RF Receiver Module (SWRF).

**Never** connect a router/repeater radio (SWPR) or digital pulse counter radio (SWS-DPC) to a BMS I/O interface.




## Analog outputs (AO1 to AO4):

Analog sensor values (e.g. temperature, relative humidity, voltage) can be mapped to analog outputs. The sensor values are represented as 0-5VDC or 0-10VDC signals (scaling is user configurable through NQ program).

## Digital outputs (S1 to S4):

Digital sensor values (e.g. pulse counter, digital input) can be mapped to digital outputs. Outputs are solid state dry contacts and switch to ground. Outputs can be directly connected to building automation controllers' dry contact input. Connecting to digital PLC inputs usually requires a pull-up resistor. The output behavior can be configured using NQ.

## Status output:

This output indicates low battery condition or communication time out of connected sensors (> 45 minutes). The status output behavior (latched or pulse) can be configured through NQ.

## LEDs

| LED | Description |
|---|---|
| LED1 | Flashes green when a packet is received/ transmitted by the receiver radio |
| LED2 | Stays green during device operation. When device is rebooted, it turns off and turns on again. |
| LED3 | Turns red when the receiver radio cable is unplugged. |
| LED4 | Stays green, indicating good 3.3V power |
| LED5 | Stays amber, indicating good 12V power |

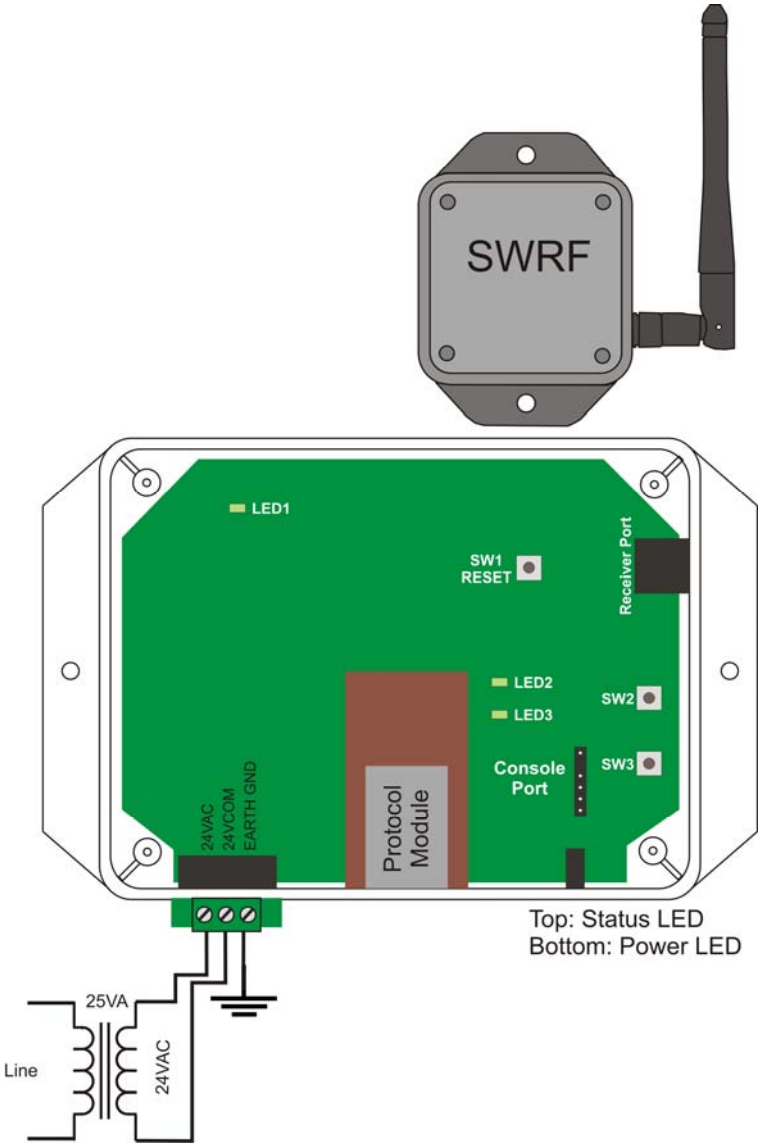
## BUTTONs

| Button | Description |
|---|---|
| RESET | Push to reboot the SWRF-IOR |
| SW3 | Push to reset the STATUS output and all digital outputs |

# SWRF-LON, SWRF-BACNET, SWRF-MODBUS: BMS Protocol Interface with Remote RF Receiver Module

The BMS Protocol Interface is designed to interface with open protocol building automation networks.

The BMS Protocol Interface is intended for wall-mount installation inside a control panel. For best RF performance, the RF Receiver must be mounted outside of metal enclosures in an area of good RF propagation. The Receiver's antenna should always point up or down (vertical orientation).



The Receiver module is connected to the protocol gateway (Receiver Port) using a standard CAT5 patch cable (Ethernet cable). This allows to remotely mount the receiver radio up to 30 feet away from the gateway.

Please see Appendix B for changing the gateway's IP address, Node ID or baud rate.

## LEDs

| LED | Description |
|---|---|
| LED1 | 5VDC Power LED; stays green during operation. |
| LED3 | Stays green during operation. |
| Status (Top) | Solid red: radio not connected<br>Blinking red: Protocol module booting-up<br>Blinking red/green: Console port in use<br>Blinking green: radio message received |
| Power (Bottom) | 3.3VDC Power LED; stays green during operation. |

## BUTTONs

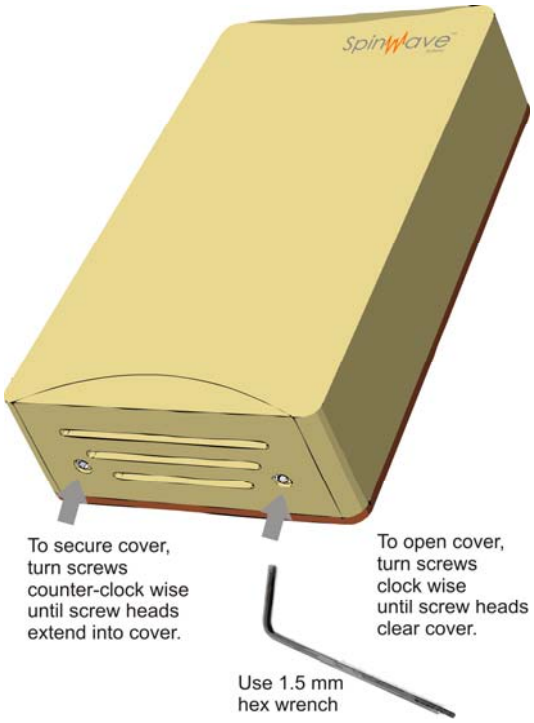
| Button | Description |
|---|---|
| SW1 (RESET) | Push to reboot the receiver/gateway |

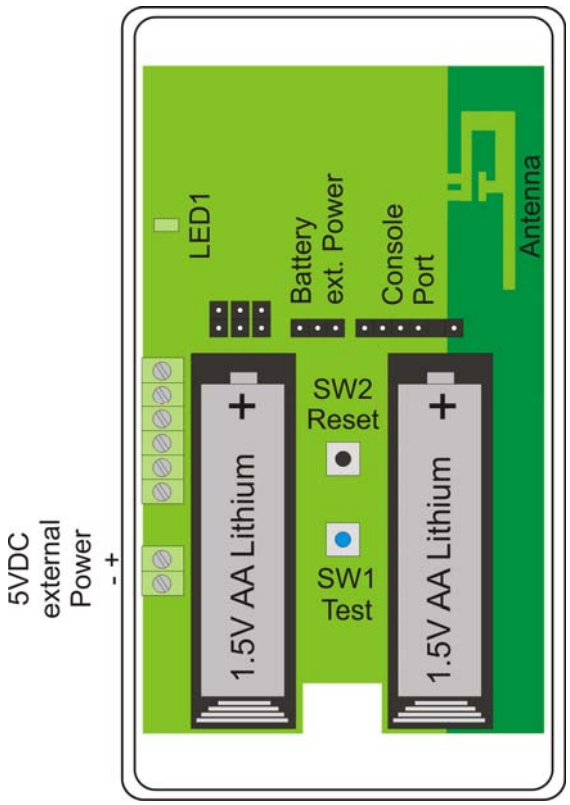
When the NQ cable is plugged into the gateway's Console Port, the BMS Interface will not communicate through its BMS interface port and Modbus, LON or BACnet values will not update. **Unplug the NQ cable after the wireless network has been configured.**
Never connect a repeater radio (SWRP) or a pulse counter radio (SWS-DPC) to the gateway, always use the SWRF receiver module.

## Sensors and Transceivers

Spinwave's wireless sensors and transceivers are used to wirelessly transmit temperature, relative humidity and analog signals to a receiver and make them available as BACnet, LON or Modbus variables using a BMS Protocol Interface or as analog outputs using a BMS I/O interface.

Sensor enclosures are locked by two security screws in the enclosure base. Before removing the cover, make sure that the security screws are turned in enough to clear the cover.


To secure cover, turn screws counter-clock wise until screw heads extend into cover.
To open cover, turn screws clock wise until screw heads clear cover.
Use 1.5 mm hex wrench




The left diagram shows battery installation, LED, pushbutton and jumper locations of a Spinwave wireless zone sensor.

Before inserting sensor batteries, make sure your receiver is powered up. Observe polarity when inserting batteries and move the power jumper to the "Battery" position (over the left two pins).

All sensors can be optionally powered by a 5VDC external supply. In this case, the sensor will also act as a repeater. For external power, the power jumper has to be moved to the right position (over the two right pins).

The "Console Port" can be used to connect the USB configuration cable to access the wireless sensor network. In this case move the power jumper to "EXT". This will ensure that the sensor is powered by your PC's USB port and will prevent the sensor from entering sleep mode.

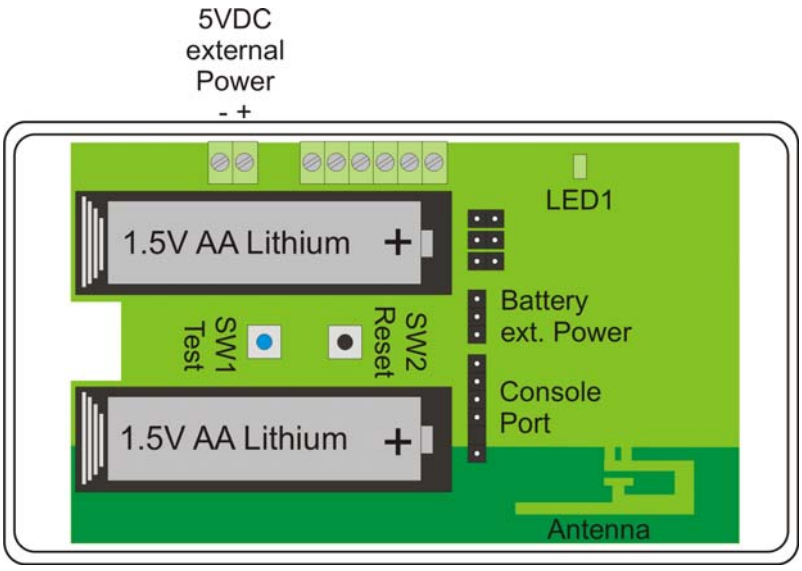
The sensor's LED1 will start blinking green a few seconds after the sensor is powered up, indicating that the sensor is trying to connect to a network. When successfully connected to the network, the LED will flash periodically green when the sensor transmits data. LED1 will briefly flash red when the sensor has been "woken up" by the NQ software.

Pushing the "Reset" button will force the sensor to transmit.

Make sure that the RF Receiver is powered up and functioning **before** powering-up related sensors. Sensors will periodically try to establish communication with the RF Receiver. If no Receiver is found, the sensor will retry to communicate until its batteries are drained. The sensor paces its retries slower and slower. **In this case battery life will be shortened from 3 to 8 years to a few months.** When a receiver is connected to the system, the sensor might not show up immediately due to the slower pace of retry. Press the RESET button on the sensor for immediate connection.

## Sensor Reset Instructions

If a sensor that has been previously bound to a wireless network should join another network (with a different PAN ID), its PAN ID has to be set to ZERO. Only sensors with PAN ID = 0 can join a new network!




## Sensor Reset Sequence (set PAN ID to zero)

| Action | Result |
|---|---|
| 1. Press and HOLD the TEST button | |
| 2. While holding the TEST button, push and RELEASE the RESET button | The LED will blink RED, then turn solid RED |
| 3. When LED is solid red, release the TEST button. | The sensor has been reset to factory settings (PAN ID = 0) and can now join any network. |

If more than one wireless network has been installed in proximity, “new” sensors (with PANID=0) might not join the designated network (a sensor will join the network with the strongest wireless signal). In this case it might be required to power all but the desired receiver down before pushing the sensor’s reset button to join the correct receiver.

## SWS-DPC: Wireless Pulse Counter

Spinwave Systems' Pulse Counters are used to wirelessly transmit electric/water/gas meter values (accumulated pulses and pulses per time) and make them available as BACnet, LON or Modbus variables using Spinwave's BMS Protocol Interface or as digital outputs (pulse replication) using a BMS I/O Interface.

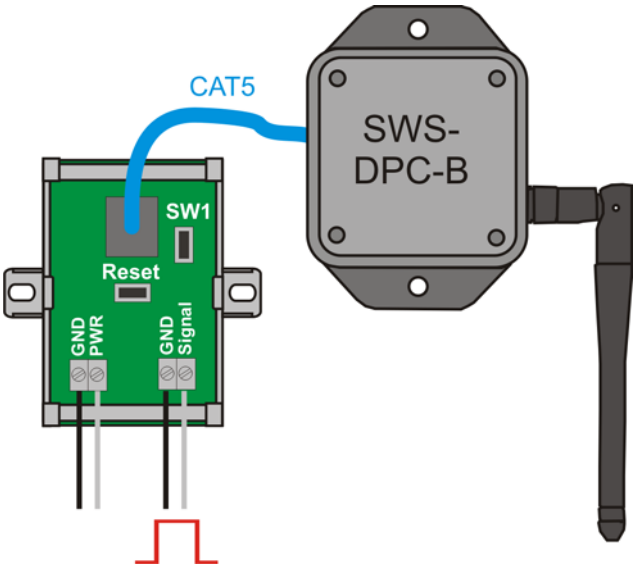
The Pulse Counter consists of a high-power radio and a signal conditioning module. The radio is connected through a standard CAT5 cable to the signal conditioning module, providing signal and power to the radio.

Pulse Counters can be battery or line-powered. A set of 6 D-Cell batteries (2 sets of 3 D-cells in parallel) will last for up to 8 years. Pulse counters are suited for both indoor and outdoor applications (when mounted in weather-proof enclosure).

Up to 50 pulse counters can be wirelessly connected to a single BMS protocol gateway (SWRF-MODBUS-TCP, SWRF-MODBUS-RTU, SWRF-BACNET-IP, SWRF-BACNET-MSTP, SWRF-LON) for remote metering applications.

Up to 4 pulse counters can be wirelessly connected to a single BMS I/O interface (SWRF-IOR or SWRF-IOR-D) for wireless pulse replication.

Wireless Repeaters/Routers are available to cover large indoor or outdoor areas. Wireless pulse counters can be used in conjunction with any other Spinwave sensor on the same wireless network.



The pulse counter can count pulses (dry contact closures) of up to 90Hz. The minimum pulse width is 10ms. The pulse counter has to be powered by a 3.6V to 9V DC power source (batteries or power supply). The radio will automatically assume repeater/router functionality above 5.5VDC and the power consumption will increase significantly. When using battery power, it is recommended to power the device by 3 D-Cells, wired in series. A second set of 3 D-Cells should be wired in parallel for prolonged battery life (up to 8 years) and the ability to change batteries without disrupting operation.

The accumulated counter value is stored in the pulse counter's RAM and transmitted periodically. This ensures that correct counter values will be received by the BMS interface, even in bad RF environments.
When used in conjunction with a BMS Protocol Interface (LON, BACnet, or Modbus), 4 different values are accessible per pulse counter:

- Periodic_Count (Float)
- Low_Count (Float)
- High_Count (Float)
- Status (Integer)

All count values are of floating point type (Note: occupy 2 Modbus registers each). In order to compute the total accumulated pulses use the following formula:

Total_accumulated_Pulses = Low_Count + 65536 * Hi_Count
The maximum pulse count can be $2^{32}$ -1.

When the pulse counter is used in conjunction with the BMS Direct I/O Interface, the pulse input is mapped to one of the I/O Interface's digital outputs. The digital output replicates the pulses. NQ can be used to configure the pulse frequency and pulse width.

When using the BMS Direct I/O interface it is important to maintain power at the I/O interface to avoid dropped pulses.

Regulations might require the use of an intrinsically safe barrier for gas metering applications.

For outdoor installations, mount the pulse counter inside a weatherproof plastic enclosure or purchase the SWS-DPC-N4 option (mounted in NEMA4X fiber glass enclosure)

If a pulse counter that has been previously bound to a wireless network should join another network (with a different PAN ID), its PAN ID has to be set to ZERO. Only sensors with PAN ID = 0 can join a new network!

## Pulse Counter Reset Sequence (set PAN ID to zero)

| Action | Result |
|---|---|
| 1. Open the radio cover in order to see the LED. | |
| 2. Press and HOLD the SW1 button in the DPC. | |
| 3. While holding the SW1 button, push and RELEASE the RESET button. Wait 5 seconds. | The LED on the radio will turn solid red. |
| 4. Release the SW1 button. | The sensor has been reset to factory settings (PAN ID = 0) and can now join any network. |

If more than one wireless network has been installed in proximity, “new” pulse counters (with PANID=0) might not join the right network (it will join the network with the strongest wireless signal). In this case it might be required to power down all receivers except the desired receiver before pushing the sensor’s reset button.

## SWS-2PT100: RTD Transceiver

Spinwave Systems' RTD transceivers are used to wirelessly transmit two PT100 temperature values and make them available as BACnet, LON or Modbus variables using Spinwave's BMS Protocol Interface.

The SWS-2PT100 supports up to two 2-wire or 3-wire PT100 temperature probes.

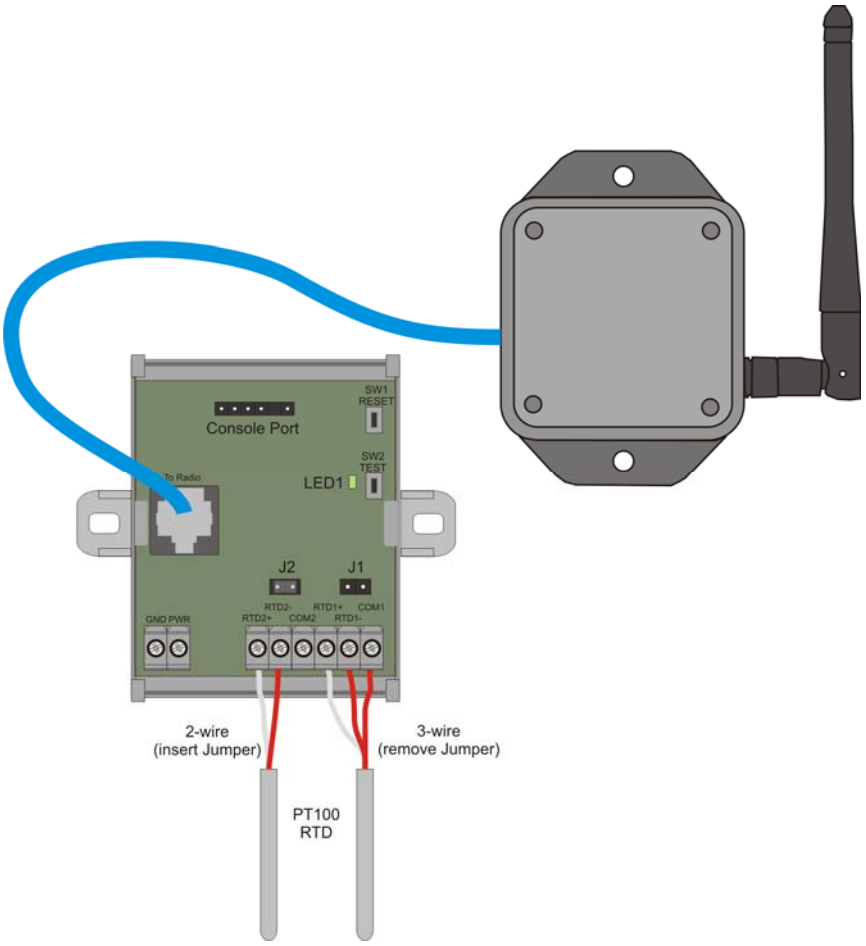
The RTD transceiver consists of a high-power radio and a signal conditioning module. The radio is connected through a standard CAT5 cable to the signal conditioning module, providing signal and power to the radio.

RTD transceivers can be battery or line-powered. A set of 6 D-Cell batteries (2 sets of 3 D-cells in parallel) will last for up to 8 years. The SWS-2PT100 is suited for both indoor and outdoor applications (when mounted in weather-proof enclosure).

If the SWS-2PT100 is powered by a 9VDC power supply, it will automatically function as a repeater.

Up to 50 SWS-2PT100 can be wirelessly connected to a single BMS protocol gateway (SWRF-MODBUS-TCP, SWRF-MODBUS-RTU, SWRF-BACNET-IP, SWRF-BACNET-MSTP, SWRF-LON) for remote temperature sensing applications.

Wireless Repeaters/Routers are available to cover large indoor or outdoor areas. Wireless pulse counters can be used in conjunction with any other Spinwave sensor on the same wireless network.




## SWS-=2PT100 Reset Sequence (set PAN ID to zero)

| Action | Result |
|---|---|
| Press and HOLD the SW2 (TEST) button. | |
| While holding the SW2 (RESET) button, push and RELEASE the RESET button. | Wait until the LED on the radio turns solid green (after about 5 seconds). |
| Release the SW2 button. | The sensor has been reset to factory settings (PAN ID = 0) and can now join any network. |

If more than one wireless network has been installed in proximity, “new” SWS-2PT100 (with PANID=0) might not join the right network (it will join the network with the strongest wireless signal). In this case it might be required to power down all receivers except the desired receiver before pushing the sensor’s reset button.

# Conducting a Site Survey

If line-of-site communication between wireless devices is not possible, it might be required to conduct a site survey to determine the number and position of repeaters.

### Optical inspection

The first step of a site survey is the optical inspection of the installation site. Wireless communication is impacted by metallic materials. This includes:

- Metal wire mesh, like chain link fencing
- Metal roofs, shields
- Metal reinforced concrete
- Shelves, appliances, electric enclosures, etc.

In the majority of cases, it is possible to establish wireless communication when metal structures are present, but it might require the strategic positioning of receiver radios and repeaters to find a communication path around those obstacles.

Bodies of water also impact wireless communication negatively. This includes:

- Dense vegetation (if you install a wireless network when there are no leaves, it might not perform as well during spring and summer).
- Snow cover
- People: A wireless system in an un-occupied building will behave differently when the building is occupied and human bodies interrupt the communication between wireless devices. If possible, mount devices high enough to clear obstacles.

Always “over-engineer” your wireless installation by observing potential future changes to the environment and accounting for them.

### Range Testing

The NQ commissioning software is capable of displaying transmit (TX) and receive (RX) signal strength for every wireless mesh network device (Device Properties).

A site survey can be conducted by temporarily placing sensors, repeaters and receivers at their designated installation location and verifying device signal strength in NQ.

The maximum signal strength for RX/TX is 255. Values >= 10 are considered good.

Repeaters (SWRP), receivers, wireless pulse counters (SW-DPC), wireless digital input modules (SWS-DI) and wireless RTD transceivers (SWS-2PT100) use high power radios and have an open field range of up to 3,500 feet.

Wireless temperature, relative humidity and analog input sensors use lower-power radios and have an open field range of up to 1,000 feet.

Both sensor types function as repeaters when they are powered by a power supply.

The following is a list of devices required for a typical range test:

- One Receiver (SWRF-IOR or SWRF-MODBUS, SWRF-BACNET, SWRF-LON)
- 24VAC power adaptor for receiver
- USB cable (SWNQBL)
- Notebook PC, running NQ software
- One repeater (SWRP) to simulate a high-power device
- One repeater power supply (SWPSUP-2) or 5VDC battery pack (e.g. 3 D-Cells)
- One wireless sensor (e.g. SWS-T) to simulate a low-power device

## System Startup Sequence

| Action | Result |
|---|---|
| Install BMS Interface and Receiver in dedicated locations. | |
| Power-up the BMS Interface. | **BMS I/O Interface:** +3.3V LED and +12V LED on DDC I/O Interface turn on.<br>LED1 on DDC I/O interface indicated communication activity with receiver module.<br><br>SWRF-IOR only: LED1 on remote RF Receiver Module turns on.<br><br>**BMS Protocol Interface:** The device required up to 6 minutes to startup. The lower green LED indicates communication activity. The upper LED indicates the device status. If no RF Receiver is connected, the Status LED will be red. If the NQ cable is plugged into the console port, the LED will blink green/red. The LED will blink red until the protocol module boots up. **Note:** The BMS protocol interface will NOT communicate with the BMS as long as the NQ cable is plugged into the console port.<br>Refer to Appendix **C** for changing the BMS Protocol Interface's IP address for BACnet IP and Modbus TCP. |
| Carefully remove sensor cover. | |
| Insert batteries in sensors. | |
| Move sensor power jumper to "Battery" position. | |
| Press and release the sensor's Reset button. | Sensor LED starts flashing green, indicating binding process. LED will turn off after communication to receiver has been established and only flash very briefly at configured transmission intervals (e.g. every 21 seconds). |
| Connect NQ cable to PC's USB port and BMS Interface's console port. | |
| Start NQ to bind and configure wireless network (see Chapter 4). | |

# Chapter 4

## Commissioning

- Overview
- Launching NQ
- Binding
- Configuring Sensor Parameters
- Configuring Repeater/Router Parameters
- Opening an Existing Project
- Troubleshooting Sensor Networks

# Overview

NQ, Spinwave's laptop-resident commissioning and maintenance tool, is used to assign (bind) wireless sensors to BMS Interface Modules. During the commissioning phase, the tool is used to monitor and verify sensor readings.

NQ allows a user to:

- Connect a laptop PC through USB to a wireless sensor network through the BMS Interface Module's console port
- Import a building floor plan
- Automatically discover network devices (sensors, repeaters/routers and receivers)
- Assign (bind) sensors to BMS Interface points by graphically connecting sensor values (e.g. room temperature, set point or override button) to BMS I/O interface terminals (outputs) or BMS Protocol Interface's network variables
- Change sensor's transmission intervals, sensitivity and scaling factors
- Monitor and verify sensor data, RF link quality, and battery health

## System Requirements

NQ is based on the latest Windows technology and requires Microsoft's .NET Framework 3.5 and FTDI's virtual COM Port USB driver.

| | |
|---|---|
| **Processor** | Minimum: 400 megahertz (MHz) Pentium processor<br>Recommended:1 gigahertz (GHz) Pentium processor |
| **Operating System** | Windows XP SP2 and .NET Framework 3.5<br>Vista, Windows 7 |
| **RAM** | Minimum: 96 megabytes (MB)<br>Recommended: 256 MB |
| **Hard Disk** | Up to 500 MB of available space may be required |
| **Display** | Minimum: 800 x 600, 256 colors<br>Recommended: 1024 x 768 high color, 32-bit |

## Installation

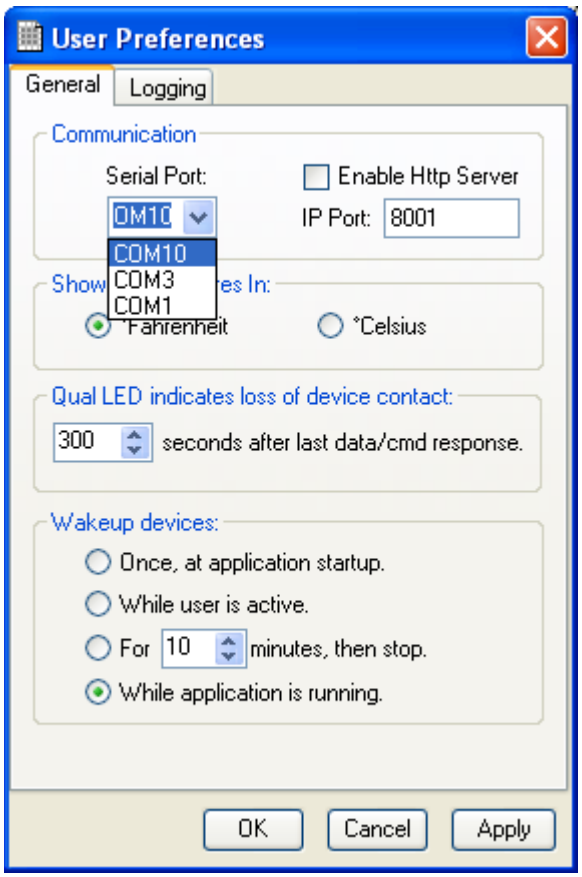
NQ can be installed from the CD or from Spinwave's support web site (http://www.spinwavesystems.com)

## Launching NQ

Connect your PC (USB port), using the NQ cable (SWNQCBL), to the BMS I/O Interface (console port), the BMS Protocol Interface or any sensor (plug into console port, move sensor power jumper to EXT position) and start-up NQ.

After NQ has been launched, go to “Network -> Preferences” and select the COM Port representing your USB connection (check via Windows Control Panel -> Device Manager).
Select the desired temperature units (“Celsius” or “Fahrenheit”), communication timeout (in seconds) and sensor wakeup options.

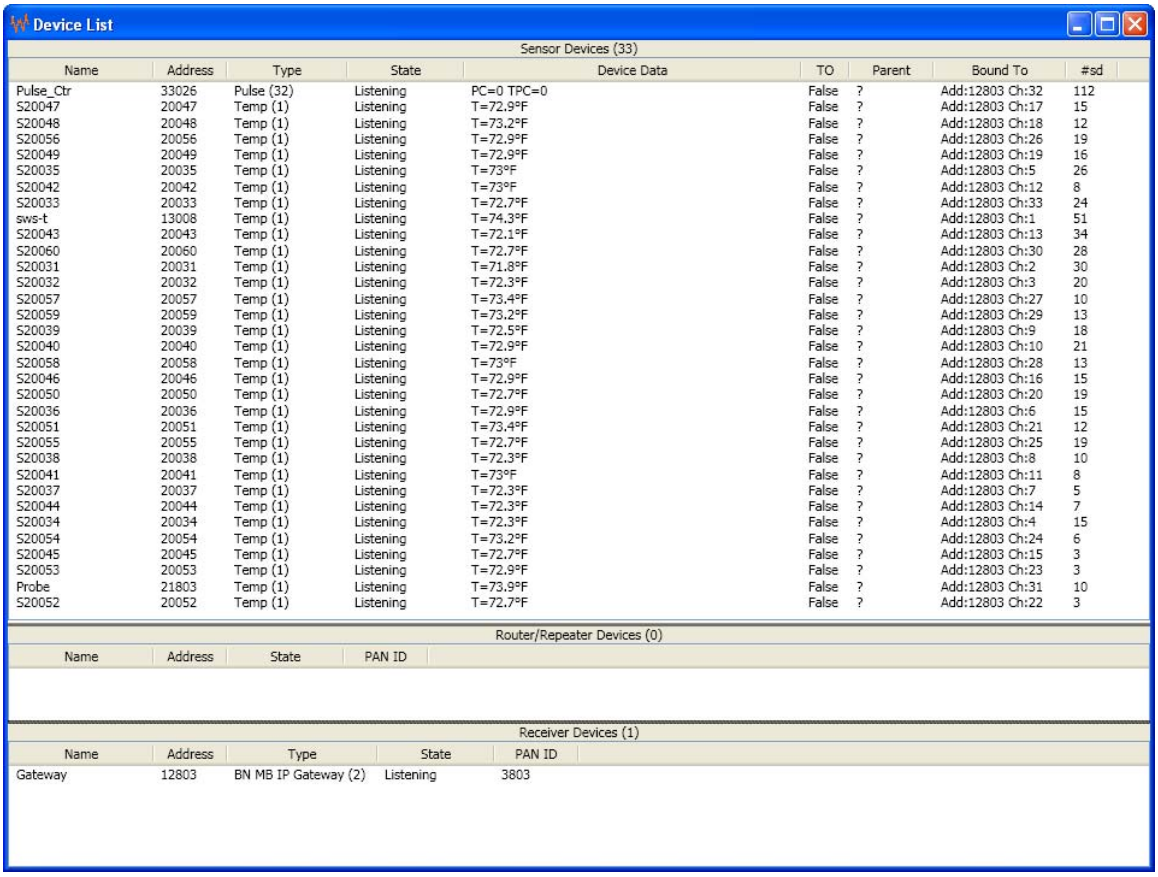
Sensor “go to sleep” after taking a measurement and transmitting the value. In order for NQ to communicate with sensors without interruption, NQ needs to “wake them up”. “Awake” sensors consume more battery power. Selecting the best wakeup option is therefore important. “Sleeping” sensors can be “woken up” by clicking the “Wake Up Devices” button on NQ’s toolbar.



## Discovering Devices

NQ will now automatically discover sensors and repeater/routers (with PAN ID = 0 or PAN ID = Receiver PAN ID) in proximity of the wireless receiver module and display them and the interface module's receiver, in the Device List. This process can take several minutes.

Additionally, sensor data is displayed, including Sensor Name, Address, Type, State, Device Data (sensor variables), Communication Timeout (TO, True or False), Parent and Binding Information. The values are wirelessly retrieved from sensors, repeaters/routers and Interface modules and are updated in the "Device List" as soon as they are acquired. This process may take several minutes to complete. Devices that have been completely discovered will be in the status of "Listening".


Device List
Sensor Devices (33)
Name Address Type State Device Data TO Parent Bound To #sd
Pulse_Ctr 33026 Pulse (32) Listening PC=0 TPC=0 False ? Add:12803 Ch:32 112
S20047 20047 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:17 15
S20048 20048 Temp (1) Listening T=73.2°F False ? Add:12803 Ch:18 12
S20056 20056 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:26 19
S20049 20049 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:19 16
S20035 20035 Temp (1) Listening T=73°F False ? Add:12803 Ch:5 26
S20042 20042 Temp (1) Listening T=73°F False ? Add:12803 Ch:12 8
S20033 20033 Temp (1) Listening T=72.7°F False ? Add:12803 Ch:33 24
sws-t 13008 Temp (1) Listening T=74.3°F False ? Add:12803 Ch:1 51
S20043 20043 Temp (1) Listening T=72.1°F False ? Add:12803 Ch:13 34
S20060 20060 Temp (1) Listening T=72.7°F False ? Add:12803 Ch:30 28
S20031 20031 Temp (1) Listening T=71.8°F False ? Add:12803 Ch:2 30
S20032 20032 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:3 20
S20057 20057 Temp (1) Listening T=73.4°F False ? Add:12803 Ch:27 10
S20059 20059 Temp (1) Listening T=73.2°F False ? Add:12803 Ch:29 13
S20039 20039 Temp (1) Listening T=72.5°F False ? Add:12803 Ch:9 18
S20040 20040 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:10 21
S20058 20058 Temp (1) Listening T=73°F False ? Add:12803 Ch:28 13
S20046 20046 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:16 15
S20050 20050 Temp (1) Listening T=72.7°F False ? Add:12803 Ch:20 19
S20036 20036 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:6 15
S20051 20051 Temp (1) Listening T=73.4°F False ? Add:12803 Ch:21 12
S20055 20055 Temp (1) Listening T=72.7°F False ? Add:12803 Ch:25 19
S20038 20038 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:8 10
S20041 20041 Temp (1) Listening T=73°F False ? Add:12803 Ch:11 8
S20037 20037 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:7 5
S20044 20044 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:14 7
S20034 20034 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:4 15
S20054 20054 Temp (1) Listening T=73.2°F False ? Add:12803 Ch:24 6
S20045 20045 Temp (1) Listening T=72.7°F False ? Add:12803 Ch:15 3
S20053 20053 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:23 3
Probe 21803 Temp (1) Listening T=73.9°F False ? Add:12803 Ch:31 10
S20052 20052 Temp (1) Listening T=72.7°F False ? Add:12803 Ch:22 3
Router/Repeater Devices (0)
Name Address State PAN ID
Receiver Devices (1)
Name Address Type State PAN ID
Gateway 12803 BN MB IP Gateway (2) Listening 3803

Wireless devices (Sensors or Routers/Repeaters) in proximity that have not been previously bound to a BMS Interface ("Receiver Device") will have a PAN ID (network ID) of zero (0) and will not display a "Parent" device or "Bound To" property. Some sensor properties will populate only when you click on the sensor and select "Properties". To obtain the properties of all

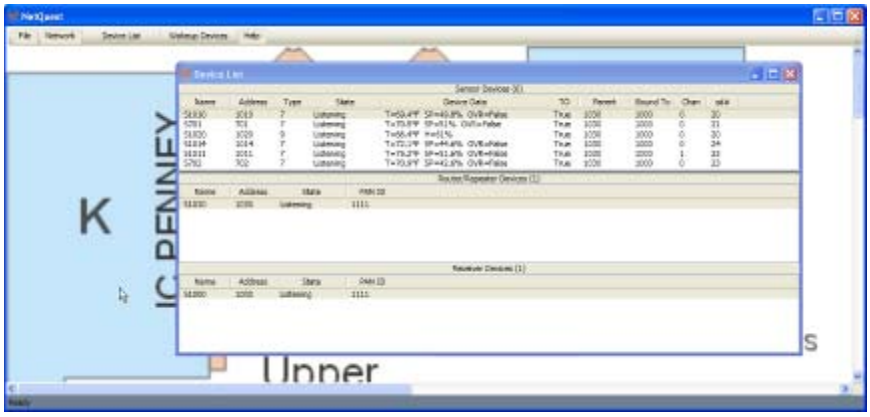
devices, click on “Network” -> “Get Device Properties” (can take several minutes).

The “#sd” column contains a message counter for each sensor. The counter value increments when a new sensor message is received.

The “TO” column indicated a sensor communication timeout according to the timeout setting specified in NQ.

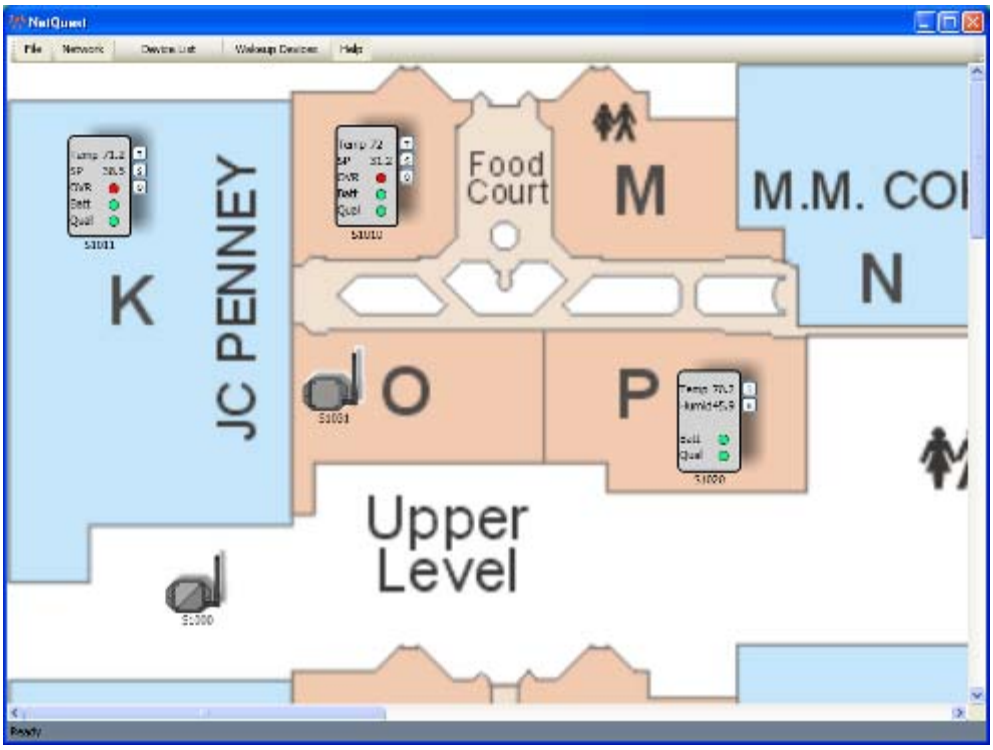
## Importing a Building Floor Plan

Go to Menu Item “File -> New Project” and select a building floor plan image file. The image becomes your window canvas.



A right click on the canvas allows enabling scaling of the floor plan. To scale, click and hold down the left mouse button over the image and drag to the right bottom corner.

Wireless devices can be dragged from the Device List and dropped onto the floor plan canvas. This allows identifying and locating sensors after installation.




Device icons and their meaning:

| Wireless Sensor | BMS I/O Interface | BMS Protocol Interface | Router/Repeater |
|---|---|---|---|
| | | | |

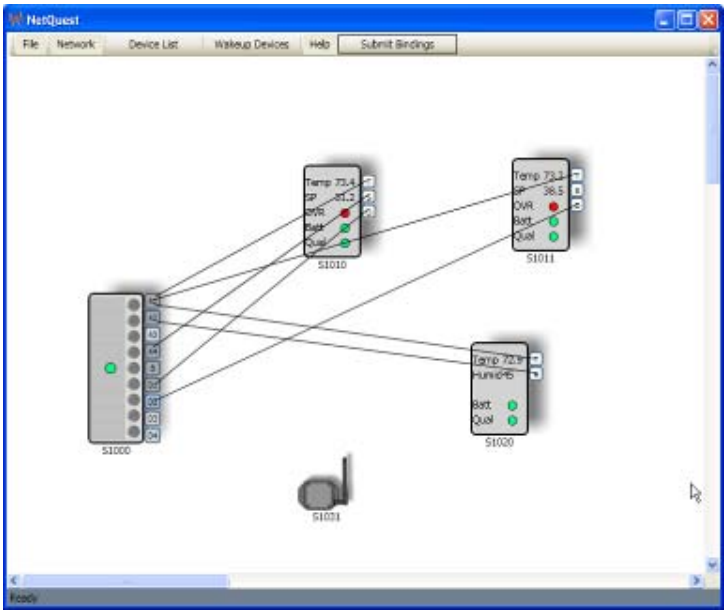
Devices that have not been bound previously or whose binding information has been cleared by the user (with a PAN ID of zero = factory default) will flash slowly.

Device Icons can be “minimized” and restored by double clicking.

## Binding Sensors and Repeaters to a BMS I/O Interface

To assign (bind) sensors to a BMS I/O Interface, select “Network -> Configuration”.

To bind sensor signals to I/O Interface outputs, click on a sensor terminal (e.g. “T” for temperature), move the cursor to a receiver’s output terminal (e.g. “A1”) and click to connect. After all connections have been performed click on “Submit Bindings” to wirelessly update the network configuration.




Connecting multiple temperature values to the same analog output will automatically average the zone temperatures of those sensors. Connecting multiple override signals to the same digital output will “OR” the override button signals.

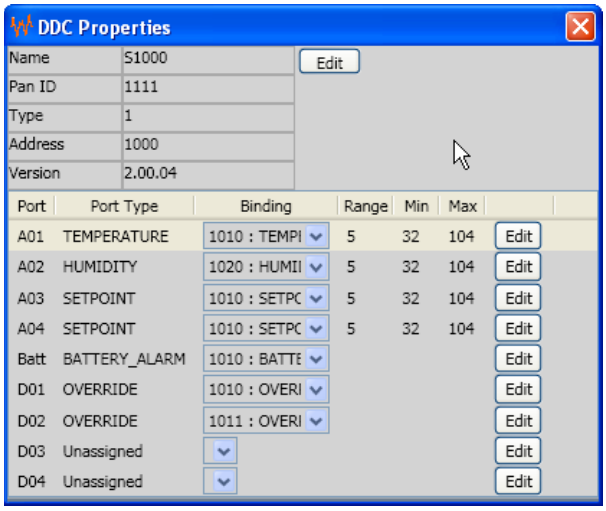
Existing Sensor bindings can be deleted by selecting “Clear Bindings” on the menu bar.

In order to bind a new repeater to the BMS Interface’s receiver, drag the repeater icon and drop it onto the receiver icon. The repeater will assume the PAN ID of the receiver.

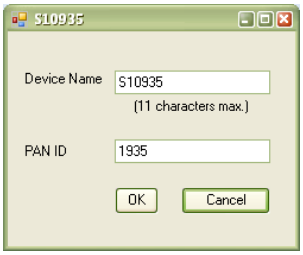
## Changing BMS I/O Interface Properties

A right click on the BMS I/O Module Icon allows viewing its properties, e.g. name, address, firmware version, binding information, output scaling and PAN ID. The PAN ID (Personal Area Network ID) property allows assigning a network id to the wireless sensor network. If several independent wireless

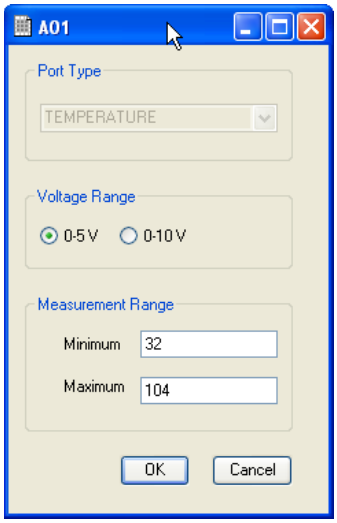
networks are deployed in the same area (e.g. building), they need to have different PAN IDs.




The Device Name and PAN ID of the BMS I/O Interface can be changed after clicking the “Edit” button.

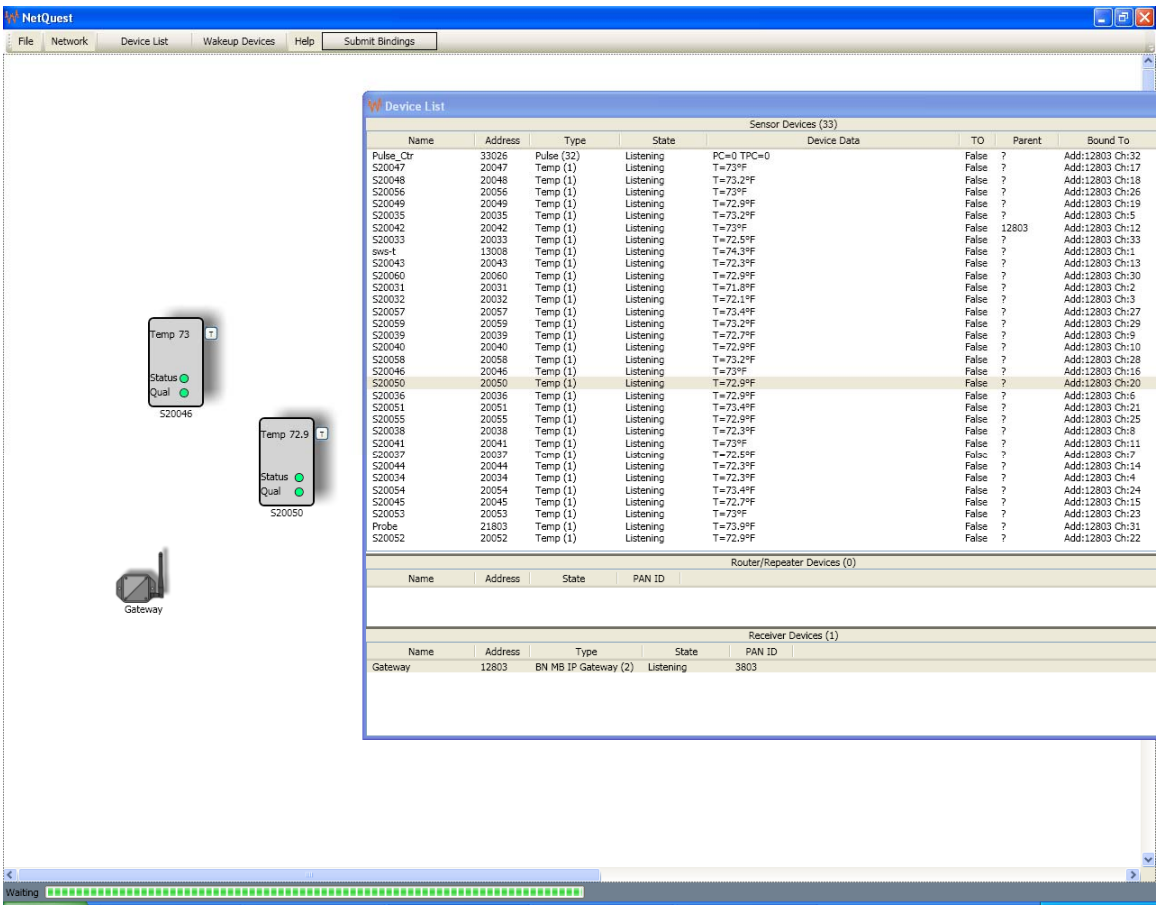



The voltage range (0-5V or 0-10V) and the Measurement Range of the corresponding analog output can be configured (e.g. a range of 0-10V, a Minimum Measurement Range of 0 and a Maximum Measurement Range of 100 will produce 0V at 0 DegF and 10.0V at 100 DegF).



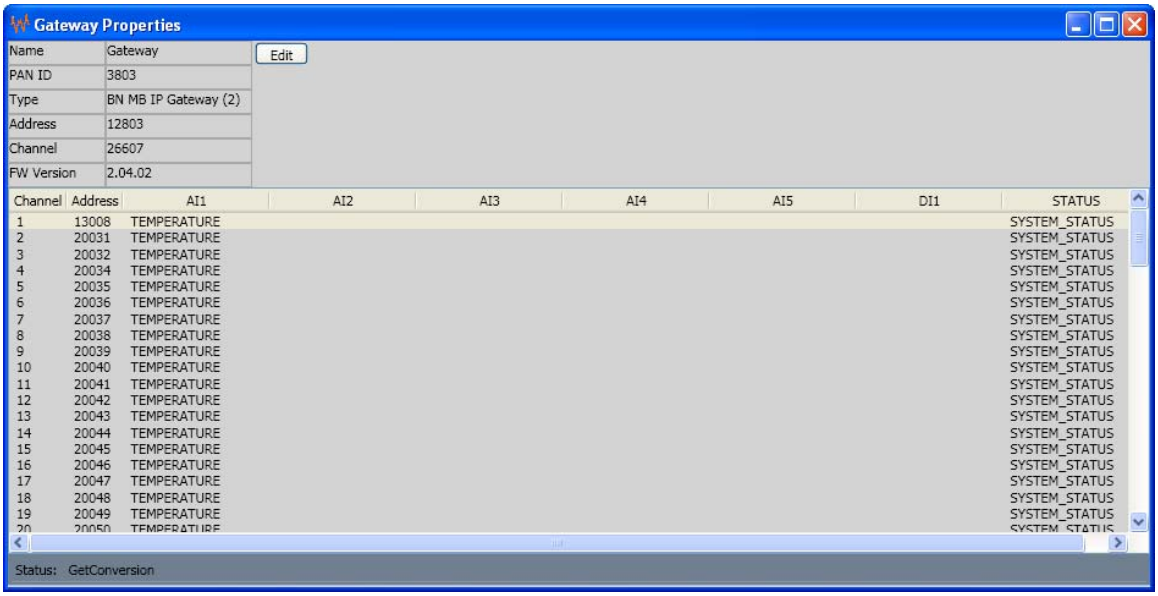
# Binding Sensors and Repeaters to a BMS Protocol Gateway

BMS Protocol Gateways have pre-configured network variables (BACnet objects, LON SNVTs or Modbus registers). The quickest way to bind sensors to those network variables is by dragging/dropping a sensor icon onto the BMS Protocol Interface Icon. The specific sensor will be mapped to the next available network "channel" (a channel consists of Analog Inputs [e.g. mapped to a sensor temperature value], Digital inputs and Sensor Status [indicating battery and communication health]).

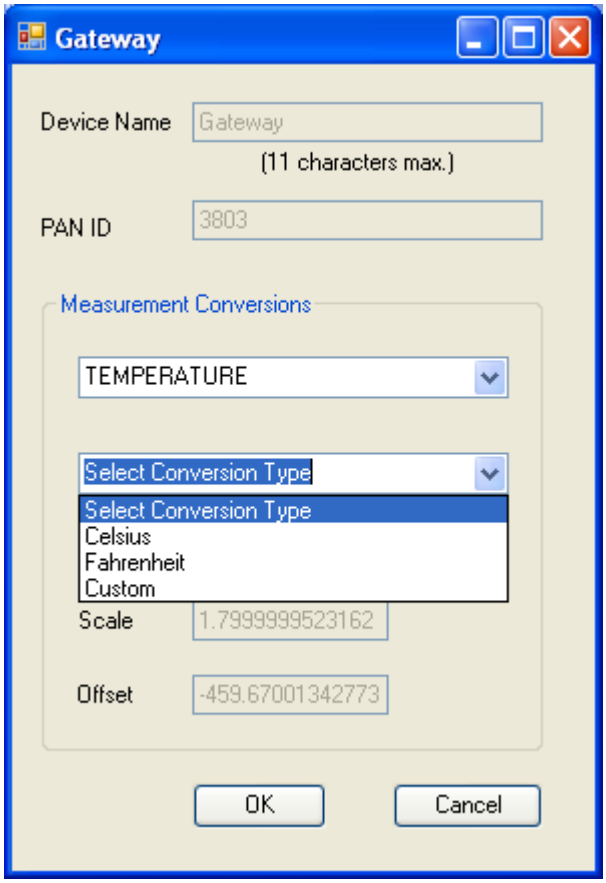

NetQuest
File
Network
Device List
Wakeup Devices
Help
Submit Bindings
Temp 73
Status
Qual
S20046
Temp 72.9
Status
Qual
S20050
Gateway
Device List
Sensor Devices (33)
Name Address Type State Device Data TO Parent Bound To
Pulse_Ctr 33026 Pulse (32) Listening PC=0 TPC=0 False ? Add:12803 Ch:32
S20047 20047 Temp (1) Listening T=73°F False ? Add:12803 Ch:17
S20048 20048 Temp (1) Listening T=73.2°F False ? Add:12803 Ch:18
S20056 20056 Temp (1) Listening T=73°F False ? Add:12803 Ch:26
S20049 20049 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:19
S20035 20035 Temp (1) Listening T=73.2°F False ? Add:12803 Ch:5
S20042 20042 Temp (1) Listening T=73°F False 12803 Add:12803 Ch:12
S20033 20033 Temp (1) Listening T=72.5°F False ? Add:12803 Ch:33
sws-t 13008 Temp (1) Listening T=74.3°F False ? Add:12803 Ch:1
S20043 20043 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:13
S20060 20060 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:30
S20031 20031 Temp (1) Listening T=71.8°F False ? Add:12803 Ch:2
S20032 20032 Temp (1) Listening T=72.1°F False ? Add:12803 Ch:3
S20057 20057 Temp (1) Listening T=73.4°F False ? Add:12803 Ch:27
S20059 20059 Temp (1) Listening T=73.2°F False ? Add:12803 Ch:29
S20039 20039 Temp (1) Listening T=72.7°F False ? Add:12803 Ch:9
S20040 20040 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:10
S20058 20058 Temp (1) Listening T=73.2°F False ? Add:12803 Ch:28
S20046 20046 Temp (1) Listening T=73°F False ? Add:12803 Ch:16
S20050 20050 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:20
S20036 20036 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:6
S20051 20051 Temp (1) Listening T=73.4°F False ? Add:12803 Ch:21
S20055 20055 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:25
S20038 20038 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:8
S20041 20041 Temp (1) Listening T=73°F False ? Add:12803 Ch:11
S20037 20037 Temp (1) Listening T=72.5°F False ? Add:12803 Ch:7
S20044 20044 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:14
S20034 20034 Temp (1) Listening T=72.3°F False ? Add:12803 Ch:4
S20054 20054 Temp (1) Listening T=73.4°F False ? Add:12803 Ch:24
S20045 20045 Temp (1) Listening T=72.7°F False ? Add:12803 Ch:15
S20053 20053 Temp (1) Listening T=73°F False ? Add:12803 Ch:23
Probe 21803 Temp (1) Listening T=73.9°F False ? Add:12803 Ch:31
S20052 20052 Temp (1) Listening T=72.9°F False ? Add:12803 Ch:22
Router/Repeater Devices (0)
Name Address State PAN ID
Receiver Devices (1)
Name Address Type State PAN ID
Gateway 12803 BN MB IP Gateway (2) Listening 3803
Waiting

## Changing BMS Interface Properties

A right click on the BMS Protocol Interface icon allows viewing its properties.




The Device Name, PAN ID and Measurement Conversions of the BMS Protocol Interface can be changed after clicking the “Edit” button.




Conversions for the most common measurement types are pre-configured (e.g. Celsius and Fahrenheit for Temperature). The “Scale” and “Offset” entries allow accommodating custom or unusual conversions (example: There are many different possible measurement units for pressure).

# BACnet Protocol Map

| BACnet Object Type | BACnet Object Name | Comment | |
|---|---|---|---|
| Device | SWRF_BACNET_IP | Device name of Spinwave Protocol Interface | |
| Analog Inputs | CH1_ADDRESS | Spinwave end device address, e.g. sensor address | Channel 1:<br><br>BACnet objects represent values of a wireless end device, e.g. zone sensor.<br><br>An end device is mapped to a channel using NQ software. |
| | CH1_AI1 | 1st end device value, e.g. space sensor temperature | |
| | CH1_AI2 | 2nd end device value, e.g. set point | |
| | CH1_AI3 | | |
| | CH1_AI4 | | |
| | CH1_AI5 | | |
| | CH1_Status | End device status. Indicated communication timeout and/or low battery (see below for details). | |
| Binary Inputs | CH1_DI1 | End device binary value, e.g. sensor override button status (active/inactive) | |
| .<br>.<br>. | | | |
| Analog Inputs | CH100_ADDRESS | | Channel 100 |
| | CH100_AI1 | | |
| | CH100_AI2 | | |
| | CH100_AI3 | | |
| | CH100_AI4 | | |
| | CH100_AI5 | | |
| | CH100_Status | | |
| Binary Inputs | CH100_DI1 | | |

**Note**: The BACnet MS/TP baud rate is 38400 bps. The BACnet ID is 11.

The 16 bit status register for each sensor node indicates a 2 min, 6 min, 24 min and 45 min communication timeout and/or low battery condition.

Bit 2 indicates low battery (value = 2 decimal).
Bits 1 through 4 have the following communication timeout (sensor has not communicated for xx minutes) values:

2 min timeout: 0100 (4 dec)
6 min timeout: 1000 (8 dec)
24 min timeout: 1100 (12 dec)
45 min timeout: 1101 (13 dec)

# LON Protocol Map

| | LON SNVT | Comment | |
|---|---|---|---|
| Device | SWRF_LON | Device name of Spinwave Protocol Interface | |
| Analog Inputs | nvoCH1_ADDRESS | Spinwave end device address, e.g. sensor address | Channel 1:<br><br>LON SNVTs represent values of a wireless end device, e.g. zone sensor.<br><br>An end device is mapped to a channel using NQ software. |
| | nvoCH1_AI1 | 1st end device value, e.g. space sensor temperature | |
| | nvoCH1_AI2 | 2nd end device value, e.g. set point | |
| | nvoCH1_AI3 | | |
| | nvoCH1_AI4 | | |
| | nvoCH1_AI5 | | |
| | vnoCH1_Status | End device status. Indicated communication timeout and/or low battery (see below for details). | |
| Binary Inputs | nvoCH1_DI1 | End device binary value, e.g. sensor override button status (active/inactive) | |
| . . . | | | |
| Analog Inputs | nvoCH100_ADDRESS | | Channel 50 |
| | nvoCH100_AI1 | | |
| | nvoCH100_AI2 | | |
| | nvoCH100_AI3 | | |
| | nvoCH100_AI4 | | |
| | nvoCH100_AI5 | | |
| | nvoCH100_Status | | |
| Binary Inputs | nvoCH100_DI1 | | |

**Note:** all SNVTs are of type count_inc_F

The 16 bit status register for each sensor node indicates a 2 min, 6 min, 24 min and 45 min communication timeout and/or low battery condition.

Bit 2 indicates low battery (value = 2 decimal).
Bits 1 through 4 have the following communication timeout (sensor has not communicated for xx minutes) values:

2 min timeout: 0100 (4 dec)
6 min timeout: 1000 (8 dec)
24 min timeout: 1100 (12 dec)
45 min timeout: 1101 (13 dec)

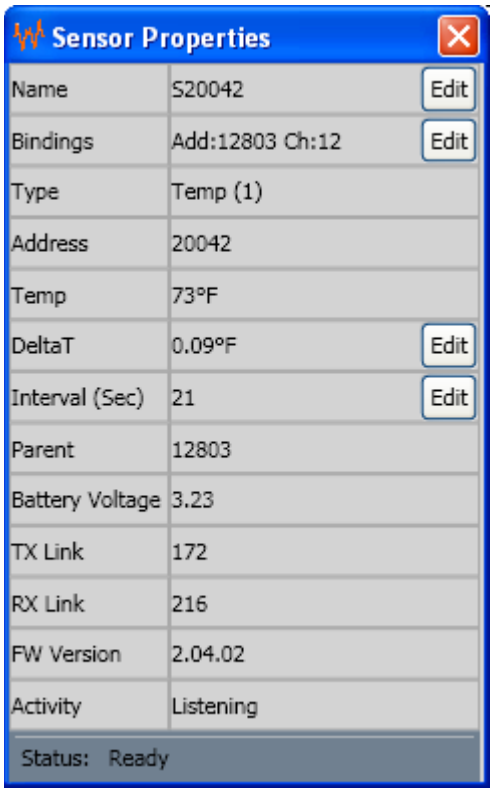
# Modbus TCP and Modbus RTU Protocol Map

| | Modbus Register | Comment | |
|---|---|---|---|
| Device | SWRF_MB | Device name of Spinwave Protocol Interface | |
| Analog Inputs | 47001, 47002 (32-bit, floating point) | Spinwave end device address, e.g. sensor address | Channel 1 (1st mapped sensor):<br><br>Modbus Holding Registers represent values of a wireless end device, e.g. zone sensor.<br><br>An end device is mapped to a channel using NQ software. |
| | 40001, 40002 (32-bit, floating point) | 1st end device value, e.g. space sensor temperature | |
| | 41001, 41002 (32-bit, floating point) | 2nd end device value, e.g. relative humidity | |
| | 42001, 42002 (32-bit, floating point) | 3rd end device value, e.g. set point | |
| | 43001, 43002 (32-bit, floating point) | 4th end device value | |
| | 44001, 44002 (32-bit, floating point) | 5th end device value | |
| | 46001 (single 16-bit register, integer) | End device status. Indicated communication timeout and/or low battery (see LON Protocol Map for details). | |
| Binary Inputs | 45001 (single 16-bit register, integer) | End device binary value, e.g. sensor override button status (active/inactive) | |
| | | | |
| Analog Inputs | 47003, 47004 | End device address | Channel 2 |
| | 40003, 40004 | 1st end device value | |
| | 41003, 41004 | 2nd end device value | |
| | 42003, 42004 | 3rd end device value | |
| | 43003, 43004 | 4th end device value | |
| | 44003, 44004 | 5th end device value | |
| | 46002 | End device status | |
| Binary Inputs | 45003 | End device binary value | |
| | | | |
| .<br>. | .<br>. | .<br>. | .<br>. |
| | | | |
| Analog Inputs | 47099, 47100 | End device address | Channel 50 |
| | 40099, 40100 | 1st end device value | |
| | 41099, 41100 | 2nd end device value | |
| | 42099, 42100 | 3rd end device value | |
| | 43099, 43100 | 4th end device value | |
| | 44099, 44100 | 5th end device value | |
| | 46050 | End device status | |
| Binary Inputs | 45099 | End device binary value | |

**Note:** For reading registers from the BMS Interface only Modbus Function Code 03 (read multiple) is supported. Some Modbus implementations (e.g. J-Bus) have an offset of zero. In this case the 1st end device value of the 1st mapped sensor is represented by holding registers 0 and 1. The default Modbus device ID is 11. The default Modbus RTU baud rate is 9600bd (no parity, 8 data bits, 1 stop bit).

## Configuring Sensor Parameters

Sensor parameters can be viewed by selecting a sensor's properties (right click on sensor icon or Device List entry) and changed by clicking the corresponding "Edit" button.




The TX Link (transmit link) and RX Link (receive link) properties indicate signal strength. The maximum value is 255. Good signal strength is present at values >= 10.

Clicking on the "Bindings" Edit button allows selectively clearing or changing bindings for the selected sensor.

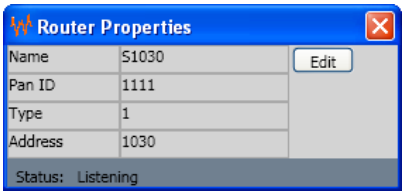
To prolong battery life it is possible to configure sensors to only transmit if the sensor value (e.g. Temperature, Humidity, Voltage) changes by a certain amount.

The "Sample Interval" is the time period between sensor transmissions. Longer Sample Intervals result in longer battery life.

After the wireless sensor network has been configured, the configuration can be saved by selecting "File ->Save Project As" on the menu bar.

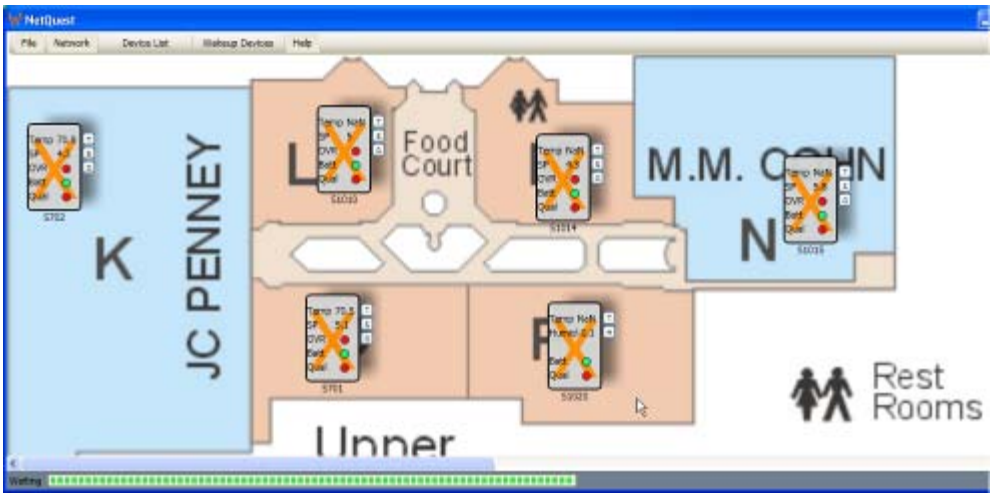
## Configuring Repeater/Router Parameters

Repeaters' Name and PAN ID can changed through their property dialog.




## Opening an Existing Project

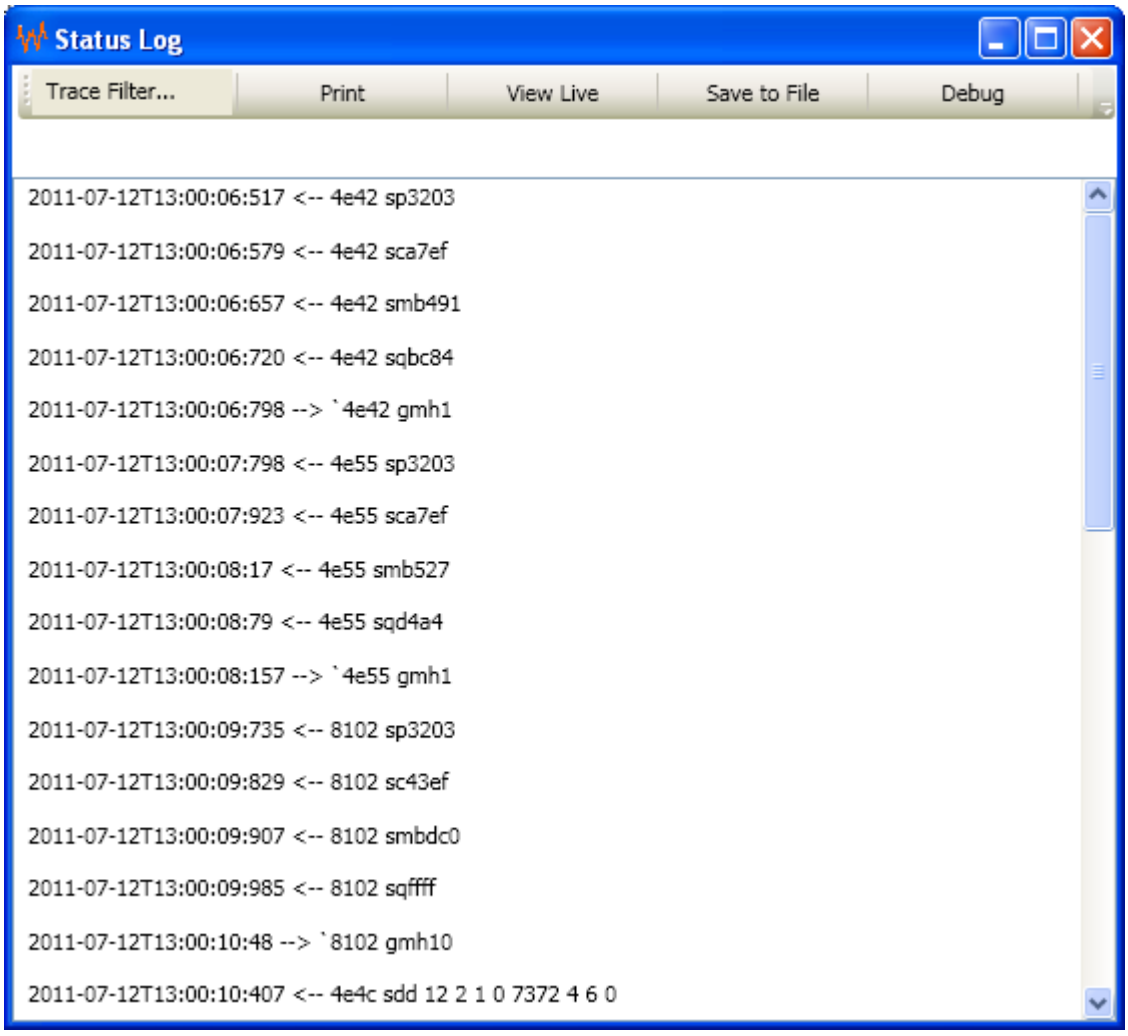
Opening a saved project will restore the floor plan, the device list and device properties. Device icons will be displayed with an orange "X" as long as they have not been discovered by NQ.




As soon as a device is discovered, the orange "X" disappears. Device icons will flash slowly as long as their PAN ID has not been acquired.

## Troubleshooting Sensor Networks

Selecting “Network -> Log View” will open a window displaying all communication messages to and from the BMS Interface Module. The Status Log Information is extremely helpful when contacting Spinwave’s technical support.

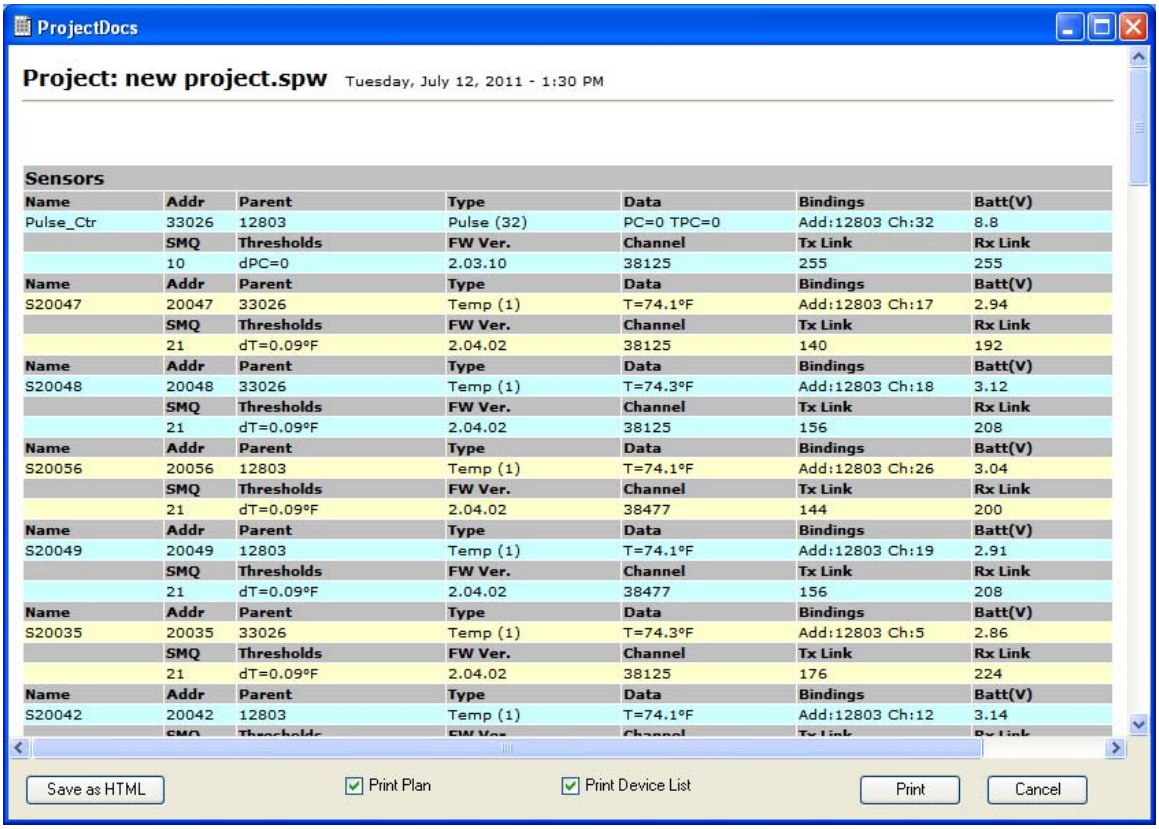



Click on “Save to File” to save the file as a text file.

# Documenting Network Configuration

After completing commissioning the complete network configuration can be printed out or saved as a HTML file.

To do this, first select “Network -> Get Device Properties” to update all sensor parameters and than select “File -> Print”.




| Name | Addr | Parent | Type | Data | Bindings | Batt(V) |
|---|---|---|---|---|---|---|
| Pulse_Ctr | 33026 | 12803 | Pulse (32) | PC=0 TPC=0 | Add:12803 Ch:32 | 8.8 |
| | SMQ | Thresholds | FW Ver. | Channel | Tx Link | Rx Link |
| | 10 | dPC=0 | 2.03.10 | 38125 | 255 | 255 |
| Name | Addr | Parent | Type | Data | Bindings | Batt(V) |
| S20047 | 20047 | 33026 | Temp (1) | T=74.1°F | Add:12803 Ch:17 | 2.94 |
| | SMQ | Thresholds | FW Ver. | Channel | Tx Link | Rx Link |
| | 21 | dT=0.09°F | 2.04.02 | 38125 | 140 | 192 |
| Name | Addr | Parent | Type | Data | Bindings | Batt(V) |
| S20048 | 20048 | 33026 | Temp (1) | T=74.3°F | Add:12803 Ch:18 | 3.12 |
| | SMQ | Thresholds | FW Ver. | Channel | Tx Link | Rx Link |
| | 21 | dT=0.09°F | 2.04.02 | 38125 | 156 | 208 |
| Name | Addr | Parent | Type | Data | Bindings | Batt(V) |
| S20056 | 20056 | 12803 | Temp (1) | T=74.1°F | Add:12803 Ch:26 | 3.04 |
| | SMQ | Thresholds | FW Ver. | Channel | Tx Link | Rx Link |
| | 21 | dT=0.09°F | 2.04.02 | 38477 | 144 | 200 |
| Name | Addr | Parent | Type | Data | Bindings | Batt(V) |
| S20049 | 20049 | 12803 | Temp (1) | T=74.1°F | Add:12803 Ch:19 | 2.91 |
| | SMQ | Thresholds | FW Ver. | Channel | Tx Link | Rx Link |
| | 21 | dT=0.09°F | 2.04.02 | 38477 | 156 | 208 |
| Name | Addr | Parent | Type | Data | Bindings | Batt(V) |
| S20035 | 20035 | 33026 | Temp (1) | T=74.3°F | Add:12803 Ch:5 | 2.86 |
| | SMQ | Thresholds | FW Ver. | Channel | Tx Link | Rx Link |
| | 21 | dT=0.09°F | 2.04.02 | 38125 | 176 | 224 |
| Name | Addr | Parent | Type | Data | Bindings | Batt(V) |
| S20042 | 20042 | 12803 | Temp (1) | T=74.1°F | Add:12803 Ch:12 | 3.14 |

# Chapter 5

## Operation/Maintenance

- Changing Batteries
- Wireless Communication

## Changing Batteries

When a sensor AA battery voltage drops below 2.745V, the DDC Interface will indicate a “Low Battery” condition. The dedicated “Status” output on the SWRF-IOR DDC I/O Interface will turn ON periodically (or the “Status” network variable of the BMS Protocol Interface will be set to “2”, respectively).

NQ will also provide information on the condition of individual sensors batteries.

Sensor batteries must be changed within a week of the first occurrence of the low battery signal to ensure uninterrupted operation. It is recommended to change batteries of all zone sensors connected to the same BMS Interface Module.

Only use specified AA Lithium batteries or high-end D-Cell alkaline batteries (SWS-DPC, SWS-DI, SWS-2PT100) as replacements.

## Wireless Communication

The dedicated “Status” output on the SWRF-IOR DDC I/O Interface will also turn on for a configurable duration when a sensor has not communicated with the RF Receiver for more than 45 minutes. The “Status” output should be configured as an alarm in the connected building automation system to alert for sensor communication problems.

The BMS Protocol Interface will set the “Status” network variable to “1” as soon as a communication timeout occurs. The variable is set to “2” if battery alarm condition occurs, and it is set to “3” if both conditions occur.

NQ will provide more detailed information on the communication condition of individual sensors.

Loss of communication can happen if the RF environment in buildings changes significantly. This can be caused by floor plan changes, installation of metal furniture, etc.

It might be necessary to add wireless repeaters to accommodate for those changes.

# Appendix A

## Troubleshooting

- Troubleshooting Guide

# Troubleshooting Guide

| Problem | Possible Cause | Resolution |
|---|---|---|
| NQ software is launched but no devices show up in the device list | Wrong COM port. | Check NQ cable. Verify COM port number under device properties to ensure the correct COM port is entered in NQ->Network->Preferences |
| Sensor does not communicate with receiver | Sensor is out of range | Move sensor closer to receiver or install repeater. **Note**: Sensor batteries will drain faster if sensor is out of range. |
| | Sensor was bound to a network and moved to another network without re-commissioning | Unbind the sensor from the original network (two button reset). Sensor will automatically show up in NQ. Bind the sensor to the new network. |
| | Sensor is in a slow retry mode to communicate with receiver resulting from a prolonged absence of the receiver. | Press the RESET button on the sensor to reboot the device and force communication. |
| | Battery problems | Measure battery voltage with a voltmeter. New Lithium AA batteries have a voltage of 1.75V. The battery voltage for the digital pulse counter needs to be minimum 3.6V, below which it will send a low battery alarm. Low battery conditions can occur when receivers are not powered on and assigned sensors periodically try to unsuccessfully establish communication and their batteries get drained. |
| | | Ensure jumper is in the correct location. If battery-powered, jumper should be in the BATT position. |
| | Same Pan ID for multiple networks | If multiple networks are installed within range, their PAN IDs must be different. Use NQ to check if PAN IDs are unique and adjust if necessary. |
| | ΔT, ΔRH, ΔP set to non-0 | Sensor will only transmit if the value change is more than the configured Δ. Wait 5 minutes to receive the most recent sensor value. |

| | | |
|---|---|---|
| | Antenna problems | Check antennas of sensor(s) and receiver. Make sure antennas are screwed in tightly and that the antenna orientation is vertical. |
| | Wrong start-up sequence | Receivers must be powered before sensors are powered. After installing sensor batteries and making sure that the power jumper is in the "Battery" position, press and releases the sensor's "reset" button. The LED will start flashing green after a few seconds and then turn off. |
| | Sensor has not being configured/ bound to the receivers PAN ID | Use NQ to bind the sensor to the receiver gateway's PAN ID.<br><br>Note: SWRF-ASCII alone cannot be used to bind a new sensor to the receiver. SWRF-IOR or any one of the SWRF-Modbus/Bacnet/Lon can be used. |
| Sensor network up and running. Suddenly some sensors don't show up in NQ. | Building interior structure may have changed.<br><br>Low sensor battery | Check battery status and link quality on sensors. If batteries are OK, contact Spinwave Support. |
| Repeater does not show up in NQ | Repeater has no power or is out of range. | Verify that the repeater is powered and in range. |
| | If there are multiple networks, repeater may be talking to another network | Power down all other receivers. Cycle repeater power. This allows the repeater to find the desired receiver and show up in NQ. |
| | The repeater may have been bound to another network | Connect the repeater radio to the gateway, and, using NQ, change PAN ID to your network's PAN ID. This binds the repeater to your network. Disconnect repeater from gateway, and deploy the repeater. Connect the gateway's original receiver radio back to the gateway. |

# Appendix B

## Changing BMS Protocol Interface Parameters

- Overview
- Changing the IP Address and Node ID (BACnet IP, Modbus TCP)
- Changing Node ID and Baud Rate (BACnet MS/TP, Modbus RTU)

# Overview

**The following applies to BACnet IP and Modbus TCP BMS Interfaces ONLY.**

The Ruinet Utility (download from support web site) is used to:

- Change a BMS Protocol Interface's IP address and Node ID
- Restart the BMS Protocol Interface

## *PC Requirements*

### Hardware

Ruinet works over an Ethernet network so a TCP/IP enabled PC with a network card is required. The network card must support 10Mbit/s Ethernet. The PC and BMS Protocol Interface can either be connected to an established network or connected directly using a **cross-over cable**.

### Software

Ruinet runs under any of the following operating systems:

- DOS
- Windows 95 (SR2 upwards),
- Windows 98,
- 2000,
- NT,
- XP
- Vista
- Windows 7

## *Installation and Setup*

The Ruinet PC's TCP/IP settings may have to be changed to successfully connect to a specific BMS Protocol Interface if there is more than one BMS Interface Modules on the network. Ruinet uses Internet Protocol to connect to a BMS Interface and therefore the Ruinet PC and the BMS Interface have to be setup with an IP address on the same subnet (e.g. IP addresses 192.168.1.24 and 192.168.1.20 are on the same subnet.).

**The BMS Protocol's default IP address is: 192.168.1.24**

If a PC is used on an already established network, it is better to change the BMS Interface's IP address than the PC's IP address.

# Changing the IP Address (BACnet-IP, MODBUS-TCP)

## Connecting to a BMS Protocol Interface

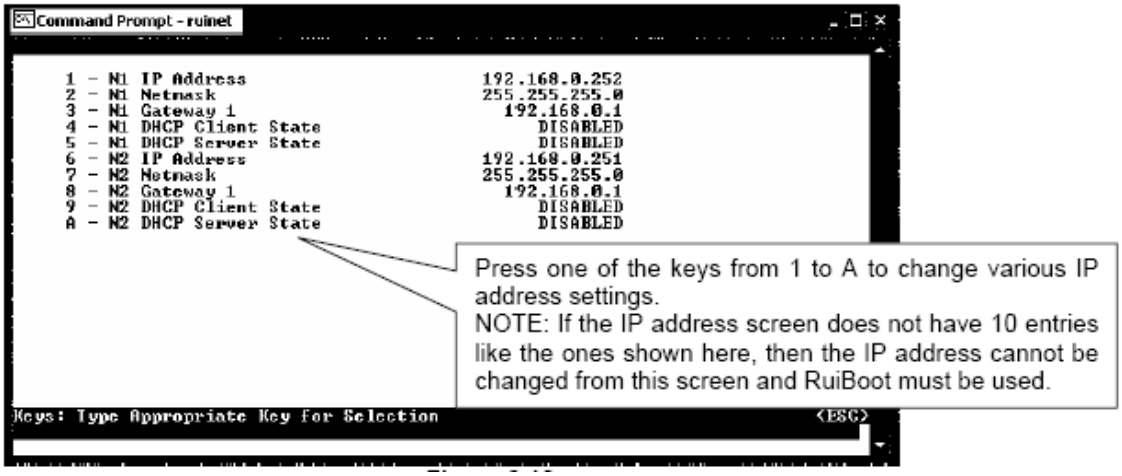
Since RuiNet can only work with one BMS Interface at a time, it is necessary to target the BMS Interface of interest. (Note that it is possible to run multiple instances of RuiNet at the same time). If RuiNet is run without specifying a target it will provide a list of the BMS Interfaces on the network. Pick the required BMS Interface from the list.

## Change IP Address

From the main menu, press ***"I"*** to enter the Edit IP Address Settings menu.

## Procedure to Change a BMS Interface's IP Address

- Press ***"1"*** to modify the IP address.
- Type in a new IP address such as 192.168.0.35 and press ***<Enter>.***
- Wait for RuiNet's response: " Type Appropriate Key for Selection".
- If necessary, press***"2"*** and change the netmask.
- If necessary, press***"3"*** and change the gateway address.
- Restart the BMS Interface using the ***"!"*** command.


Command Prompt - ruinet
1 - N1 IP Address 192.168.0.252
2 - N1 Netmask 255.255.255.0
3 - N1 Gateway 1 192.168.0.1
4 - N1 DHCP Client State DISABLED
5 - N1 DHCP Server State DISABLED
6 - N2 IP Address 192.168.0.251
7 - N2 Netmask 255.255.255.0
8 - N2 Gateway 1 192.168.0.1
9 - N2 DHCP Client State DISABLED
A - N2 DHCP Server State DISABLED
Keys: Type Appropriate Key for Selection <ESC>
Press one of the keys from 1 to A to change various IP address settings.
NOTE: If the IP address screen does not have 10 entries like the ones shown here, then the IP address cannot be changed from this screen and RuiBoot must be used.

Common IP address ranges and netmasks:

Class A – IP (1.0.0.1 to 126.255.255.254), Netmask (255.0.0.0)
Class B – IP (128.0.0.1 to 191.255.255.254), Netmask (255.255.0.0)
Class C – IP (192.0.0.1 to 223.255.255.254), Netmask (255.255.255.0)

Do not use broadcast IP address ending on 255. This IP address is reserved as a target IP address when a device wants to send a message to all other devices on the network.

## Changing the Node ID (BACNET-IP, MODBUS-TCP)

The default Node ID for all receiver/gateways is 11. It is possible to assign a different node id by changing the protocol modules config.csv file.

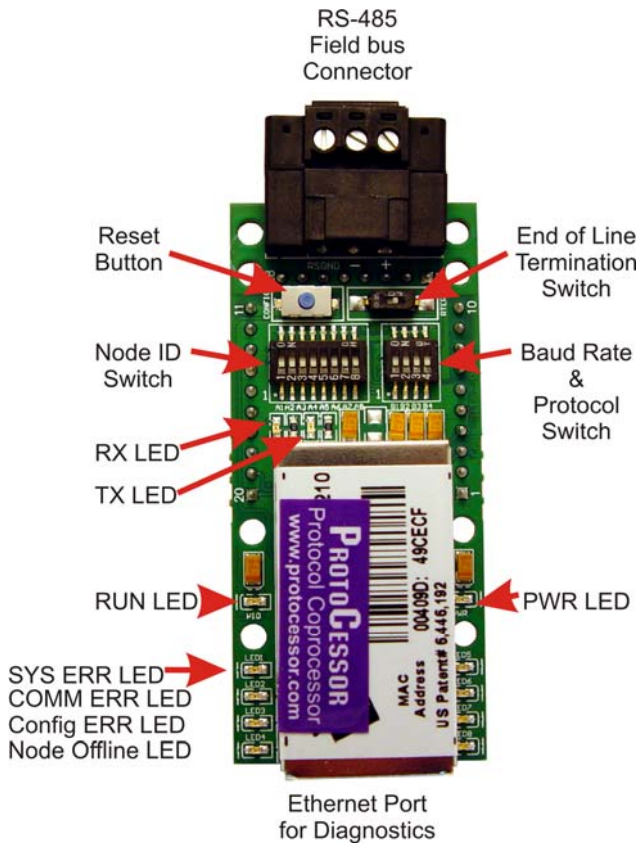
The config.csv file can be uploaded from the protocol module and saved to a PC using RUINET.

In oder to change the Node ID, locate the file on your PC and open it with **NOTEPAD** (never use EXCEL).

```
//=====================================================================
//
//    Common Information
//

Bridge
Title                    ,System_Node_Id
CN00229 Spinwave v1.01a ,11

//=====================================================================
//
.
.
.
//=====================================================================
//
//    Server Side Nodes - BACnet IP
//

Nodes,
Node_Name       ,Node_ID ,Protocol
SWRF_BACNET_IP,11,Bacnet_IP

//=====================================================================
//
```

Change the Node ID from 11 to the desired value in **TWO** places (highlighted in **red**). Save the file and load it into the protocol module. Restart the Protocol Gateway to activate the change.

# Changing Node ID and Baud Rate (BACnet MS/TP, Modbus RTU)




Network Node ID and baud rate are configured using the dedicated DIP switched (remove gateway cover for access).

Setting changes only become effective after cycling gateway power.

**Changing the baud rate** (default: 38400)

| B1 | B2 | Baud |
|---|---|---|
| Off | Off | 9600 |
| **ON** | Off | 19200 |
| Off | **ON** | 38400 |
| **ON** | **ON** | 76800 |

**Changing the protocol**

| B3 | B4 | Profile |
|---|---|---|
| Off | Off | BACnet MS/TP |
| Off | **ON** | Modbus RTU |
| **ON** | Off | Metasys N2 |

| LED | Description |
|---|---|
| PWR | Should show steady GREEN when unit is powered |
| SYS ERR | Will turn ON 15 seconds after power up. It will turn OFF after 5 seconds. A steady red light indicates a system error. |
| COMM ERR | Will turn ON 15 seconds after power up. It will turn OFF after 5 seconds. A steady red light indicates a communication problem. |
| CONFIG ERR | Will turn ON 15 seconds after power up. It will turn OFF after 5 seconds. A steady amber light indicates a configuration error in the active configuration (config.csv). |
| Node Offline | Will turn ON 15 seconds after power up. It will turn OFF after 5 seconds. Steady light indicated node offline condition. |
| RX | Flashes when a message is received. |
| TX | Flashes when a message is sent. |
| RUN | RUN LED will flash 20 seconds after power up, signifying normal operation (able to access RUINET) |

**Changing the Node ID** (default: 11)

| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | Address |
|---|---|---|---|---|---|---|---|---|
| Off | Off | Off | Off | Off | Off | Off | Off | 0 |
| **ON** | Off | Off | Off | Off | Off | Off | Off | 1 |
| Off | **ON** | Off | Off | Off | Off | Off | Off | 2 |
| **ON** | **ON** | Off | Off | Off | Off | Off | Off | 3 |
| Off | Off | **ON** | Off | Off | Off | Off | Off | 4 |
| **ON** | Off | **ON** | Off | Off | Off | Off | Off | 5 |
| Off | **ON** | **ON** | Off | Off | Off | Off | Off | 6 |
| **ON** | **ON** | **ON** | Off | Off | Off | Off | Off | 7 |
| Off | Off | Off | **ON** | Off | Off | Off | Off | 8 |
| **ON** | Off | Off | **ON** | Off | Off | Off | Off | 9 |
| Off | **ON** | Off | **ON** | Off | Off | Off | Off | 10 |
| **ON** | **ON** | Off | **ON** | Off | Off | Off | Off | **11** |
| Off | Off | **ON** | **ON** | Off | Off | Off | Off | 12 |
| **ON** | Off | **ON** | **ON** | Off | Off | Off | Off | 13 |
| Off | **ON** | **ON** | **ON** | Off | Off | Off | Off | 14 |
| **ON** | **ON** | **ON** | **ON** | Off | Off | Off | Off | 15 |
| Off | Off | Off | Off | **ON** | Off | Off | Off | 16 |
| **ON** | Off | Off | Off | **ON** | Off | Off | Off | 17 |
| Off | **ON** | Off | Off | **ON** | Off | Off | Off | 18 |
| **ON** | **ON** | Off | Off | **ON** | Off | Off | Off | 19 |
| Off | Off | **ON** | Off | **ON** | Off | Off | Off | 20 |
| **ON** | Off | **ON** | Off | **ON** | Off | Off | Off | 21 |
| Off | **ON** | **ON** | Off | **ON** | Off | Off | Off | 22 |
| **ON** | **ON** | **ON** | Off | **ON** | Off | Off | Off | 23 |
| Off | Off | Off | **ON** | **ON** | Off | Off | Off | 24 |
| **ON** | Off | Off | **ON** | **ON** | Off | Off | Off | 25 |
| Off | **ON** | Off | **ON** | **ON** | Off | Off | Off | 26 |
| **ON** | **ON** | Off | **ON** | **ON** | Off | Off | Off | 27 |
| Off | Off | **ON** | **ON** | **ON** | Off | Off | Off | 28 |
| **ON** | Off | **ON** | **ON** | **ON** | Off | Off | Off | 29 |
| **Off** | **ON** | **ON** | **ON** | **ON** | Off | Off | Off | 30 |
| **ON** | **ON** | **ON** | **ON** | **ON** | Off | Off | Off | 31 |
| Off | Off | Off | Off | Off | **ON** | Off | Off | 32 |
| **ON** | Off | Off | Off | Off | **ON** | Off | Off | 33 |
| Off | **ON** | Off | Off | Off | **ON** | Off | Off | 34 |
| **ON** | **ON** | Off | Off | Off | **ON** | Off | Off | 35 |
| Off | Off | **ON** | Off | Off | **ON** | Off | Off | 36 |
| **ON** | Off | **ON** | Off | Off | **ON** | Off | Off | 37 |
| Off | **ON** | **ON** | Off | Off | **ON** | Off | Off | 38 |
| **ON** | **ON** | **ON** | Off | Off | **ON** | Off | Off | 39 |
| Off | Off | Off | **ON** | Off | **ON** | Off | Off | 40 |
| **ON** | Off | Off | **ON** | Off | **ON** | Off | Off | 41 |
| Off | **ON** | Off | **ON** | Off | **ON** | Off | Off | 42 |
| **ON** | **ON** | Off | **ON** | Off | **ON** | Off | Off | 43 |
| Off | Off | **ON** | **ON** | Off | **ON** | Off | Off | 44 |

| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | Address |
|---|---|---|---|---|---|---|---|---|
| **ON** | Off | **ON** | **ON** | Off | **ON** | Off | Off | 45 |
| Off | **ON** | **ON** | **ON** | Off | **ON** | Off | Off | 46 |
| **ON** | **ON** | **ON** | **ON** | Off | **ON** | Off | Off | 47 |
| Off | Off | Off | Off | **ON** | **ON** | Off | Off | 48 |
| **ON** | Off | Off | Off | **ON** | **ON** | Off | Off | 49 |
| Off | **ON** | Off | Off | **ON** | **ON** | Off | Off | 50 |
| **ON** | **ON** | Off | Off | **ON** | **ON** | Off | Off | 51 |
| Off | Off | **ON** | Off | **ON** | **ON** | Off | Off | 52 |
| **ON** | Off | **ON** | Off | **ON** | **ON** | Off | Off | 53 |
| Off | **ON** | **ON** | Off | **ON** | **ON** | Off | Off | 54 |
| **ON** | **ON** | **ON** | Off | **ON** | **ON** | Off | Off | 55 |
| Off | Off | Off | **ON** | **ON** | **ON** | Off | Off | 56 |
| **ON** | Off | Off | **ON** | **ON** | **ON** | Off | Off | 57 |
| Off | **ON** | Off | **ON** | **ON** | **ON** | Off | Off | 58 |
| **ON** | **ON** | Off | **ON** | **ON** | **ON** | Off | Off | 59 |
| Off | Off | **ON** | **ON** | **ON** | **ON** | Off | Off | 60 |
| **ON** | Off | **ON** | **ON** | **ON** | **ON** | Off | Off | 61 |
| Off | **ON** | **ON** | **ON** | **ON** | **ON** | Off | Off | 62 |
| **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | Off | Off | 63 |
| Off | Off | Off | Off | Off | Off | **ON** | Off | 64 |
| **ON** | Off | Off | Off | Off | Off | **ON** | Off | 65 |
| Off | **ON** | Off | Off | Off | Off | **ON** | Off | 66 |
| **ON** | **ON** | Off | Off | Off | Off | **ON** | Off | 67 |
| Off | Off | **ON** | Off | Off | Off | **ON** | Off | 68 |
| **ON** | Off | **ON** | Off | Off | Off | **ON** | Off | 69 |
| Off | **ON** | **ON** | Off | Off | Off | **ON** | Off | 70 |
| **ON** | **ON** | **ON** | Off | Off | Off | **ON** | Off | 71 |
| Off | Off | Off | **ON** | Off | Off | **ON** | Off | 72 |
| **ON** | Off | Off | **ON** | Off | Off | **ON** | Off | 73 |
| Off | **ON** | Off | **ON** | Off | Off | **ON** | Off | 74 |
| **ON** | **ON** | Off | **ON** | Off | Off | **ON** | Off | 75 |
| Off | Off | **ON** | **ON** | Off | Off | **ON** | Off | 76 |
| **ON** | Off | **ON** | **ON** | Off | Off | **ON** | Off | 77 |
| Off | **ON** | **ON** | **ON** | Off | Off | **ON** | Off | 78 |
| **ON** | **ON** | **ON** | **ON** | Off | Off | **ON** | Off | 79 |
| Off | Off | Off | Off | **ON** | Off | **ON** | Off | 80 |
| **ON** | Off | Off | Off | **ON** | Off | **ON** | Off | 81 |
| Off | **ON** | Off | Off | **ON** | Off | **ON** | Off | 82 |
| **ON** | **ON** | Off | Off | **ON** | Off | **ON** | Off | 83 |
| Off | Off | **ON** | Off | **ON** | Off | **ON** | Off | 84 |
| **ON** | Off | **ON** | Off | **ON** | Off | **ON** | Off | 85 |
| Off | **ON** | **ON** | Off | **ON** | Off | **ON** | Off | 86 |
| **ON** | **ON** | **ON** | Off | **ON** | Off | **ON** | Off | 87 |
| Off | Off | Off | **ON** | **ON** | Off | **ON** | Off | 88 |
| **ON** | Off | Off | **ON** | **ON** | Off | **ON** | Off | 89 |
| Off | **ON** | Off | **ON** | **ON** | Off | **ON** | Off | 90 |

| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | Address |
|---|---|---|---|---|---|---|---|---|
| **ON** | **ON** | Off | **ON** | **ON** | Off | **ON** | Off | 91 |
| Off | Off | **ON** | **ON** | **ON** | Off | **ON** | Off | 92 |
| **ON** | Off | **ON** | **ON** | **ON** | Off | **ON** | Off | 93 |
| Off | **ON** | **ON** | **ON** | **ON** | Off | **ON** | Off | 94 |
| **ON** | **ON** | **ON** | **ON** | **ON** | Off | **ON** | Off | 95 |
| Off | Off | Off | Off | Off | **ON** | **ON** | Off | 96 |
| **ON** | Off | Off | Off | Off | **ON** | **ON** | Off | 97 |
| Off | **ON** | Off | Off | Off | **ON** | **ON** | Off | 98 |
| **ON** | **ON** | Off | Off | Off | **ON** | **ON** | Off | 99 |
| Off | Off | **ON** | Off | Off | **ON** | **ON** | Off | 100 |
| **ON** | Off | **ON** | Off | Off | **ON** | **ON** | Off | 101 |
| Off | **ON** | **ON** | Off | Off | **ON** | **ON** | Off | 102 |
| **ON** | **ON** | **ON** | Off | Off | **ON** | **ON** | Off | 103 |
| Off | Off | Off | **ON** | Off | **ON** | **ON** | Off | 104 |
| **ON** | Off | Off | **ON** | Off | **ON** | **ON** | Off | 105 |
| Off | **ON** | Off | **ON** | Off | **ON** | **ON** | Off | 106 |
| **ON** | **ON** | Off | **ON** | Off | **ON** | **ON** | Off | 107 |
| Off | Off | **ON** | **ON** | Off | **ON** | **ON** | Off | 108 |
| **ON** | Off | **ON** | **ON** | Off | **ON** | **ON** | Off | 109 |
| Off | **ON** | **ON** | **ON** | Off | **ON** | **ON** | Off | 110 |
| **ON** | **ON** | **ON** | **ON** | Off | **ON** | **ON** | Off | 111 |
| Off | Off | Off | Off | **ON** | **ON** | **ON** | Off | 112 |
| **ON** | Off | Off | Off | **ON** | **ON** | **ON** | Off | 113 |
| Off | **ON** | Off | Off | **ON** | **ON** | **ON** | Off | 114 |
| **ON** | **ON** | Off | Off | **ON** | **ON** | **ON** | Off | 115 |
| Off | Off | **ON** | Off | **ON** | **ON** | **ON** | Off | 116 |
| **ON** | Off | **ON** | Off | **ON** | **ON** | **ON** | Off | 117 |
| Off | **ON** | **ON** | Off | **ON** | **ON** | **ON** | Off | 118 |
| **ON** | **ON** | **ON** | Off | **ON** | **ON** | **ON** | Off | 119 |
| Off | Off | Off | **ON** | **ON** | **ON** | **ON** | Off | 120 |
| **ON** | Off | Off | **ON** | **ON** | **ON** | **ON** | Off | 121 |
| Off | **ON** | Off | **ON** | **ON** | **ON** | **ON** | Off | 122 |
| **ON** | **ON** | Off | **ON** | **ON** | **ON** | **ON** | Off | 123 |
| Off | Off | **ON** | **ON** | **ON** | **ON** | **ON** | Off | 124 |
| **ON** | Off | **ON** | **ON** | **ON** | **ON** | **ON** | Off | 125 |
| Off | **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | Off | 126 |
| **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | Off | 127 |
| Off | Off | Off | Off | Off | Off | Off | **ON** | 128 |
| **ON** | Off | Off | Off | Off | Off | Off | **ON** | 129 |
| Off | **ON** | Off | Off | Off | Off | Off | **ON** | 130 |
| **ON** | **ON** | Off | Off | Off | Off | Off | **ON** | 131 |
| Off | Off | **ON** | Off | Off | Off | Off | **ON** | 132 |
| **ON** | Off | **ON** | Off | Off | Off | Off | **ON** | 133 |
| Off | **ON** | **ON** | Off | Off | Off | Off | **ON** | 134 |
| **ON** | **ON** | **ON** | Off | Off | Off | Off | **ON** | 135 |
| Off | Off | Off | **ON** | Off | Off | Off | **ON** | 136 |
| **ON** | Off | Off | **ON** | Off | Off | Off | **ON** | 137 |

| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | Address |
|---|---|---|---|---|---|---|---|---|
| **Off** | ON | Off | **ON** | Off | Off | Off | **ON** | 138 |
| **ON** | ON | Off | **ON** | Off | Off | Off | **ON** | 139 |
| **Off** | Off | ON | **ON** | Off | Off | Off | **ON** | 140 |
| **ON** | Off | ON | **ON** | Off | Off | Off | **ON** | 141 |
| **Off** | ON | ON | **ON** | Off | Off | Off | **ON** | 142 |
| **ON** | ON | ON | **ON** | Off | Off | Off | **ON** | 143 |
| **Off** | Off | Off | **Off** | ON | Off | Off | **ON** | 144 |
| **ON** | Off | Off | **Off** | ON | Off | Off | **ON** | 145 |
| **Off** | ON | Off | **Off** | ON | Off | Off | **ON** | 146 |
| **ON** | ON | Off | **Off** | ON | Off | Off | **ON** | 147 |
| **Off** | Off | ON | **Off** | ON | Off | Off | **ON** | 148 |
| **ON** | Off | ON | **Off** | ON | Off | Off | **ON** | 149 |
| **Off** | ON | ON | **Off** | ON | Off | Off | **ON** | 150 |
| **ON** | ON | ON | **Off** | ON | Off | Off | **ON** | 151 |
| **Off** | Off | Off | **ON** | ON | Off | Off | **ON** | 152 |
| **ON** | Off | Off | **ON** | ON | Off | Off | **ON** | 153 |
| **Off** | ON | Off | **ON** | ON | Off | Off | **ON** | 154 |
| **ON** | ON | Off | **ON** | ON | Off | Off | **ON** | 155 |
| **Off** | Off | ON | **ON** | ON | Off | Off | **ON** | 156 |
| **ON** | Off | ON | **ON** | ON | Off | Off | **ON** | 157 |
| **Off** | ON | ON | **ON** | ON | Off | Off | **ON** | 158 |
| **ON** | ON | ON | **ON** | ON | Off | Off | **ON** | 159 |
| **Off** | Off | Off | **Off** | Off | ON | Off | **ON** | 160 |
| **ON** | Off | Off | **Off** | Off | ON | Off | **ON** | 161 |
| **Off** | ON | Off | **Off** | Off | ON | Off | **ON** | 162 |
| **ON** | ON | Off | **Off** | Off | ON | Off | **ON** | 163 |
| **Off** | Off | ON | **Off** | Off | ON | Off | **ON** | 164 |
| **ON** | Off | ON | **Off** | Off | ON | Off | **ON** | 165 |
| **Off** | ON | ON | **Off** | Off | ON | Off | **ON** | 166 |
| **ON** | ON | ON | **Off** | Off | ON | Off | **ON** | 167 |
| **Off** | Off | Off | **ON** | Off | ON | Off | **ON** | 168 |
| **ON** | Off | Off | **ON** | Off | ON | Off | **ON** | 169 |
| **Off** | ON | Off | **ON** | Off | ON | Off | **ON** | 170 |
| **ON** | ON | Off | **ON** | Off | ON | Off | **ON** | 171 |
| **Off** | Off | ON | **ON** | Off | ON | Off | **ON** | 172 |
| **ON** | Off | ON | **ON** | Off | ON | Off | **ON** | 173 |
| **Off** | ON | ON | **ON** | Off | ON | Off | **ON** | 174 |
| **ON** | ON | ON | **ON** | Off | ON | Off | **ON** | 175 |
| **Off** | Off | Off | **Off** | ON | ON | Off | **ON** | 176 |
| **ON** | Off | Off | **Off** | ON | ON | Off | **ON** | 177 |
| **Off** | ON | Off | **Off** | ON | ON | Off | **ON** | 178 |
| **ON** | ON | Off | **Off** | ON | ON | Off | **ON** | 179 |
| **Off** | Off | ON | **Off** | ON | ON | Off | **ON** | 180 |
| **ON** | Off | ON | **Off** | ON | ON | Off | **ON** | 181 |
| **Off** | ON | ON | **Off** | ON | ON | Off | **ON** | 182 |
| **ON** | ON | ON | **Off** | ON | ON | Off | **ON** | 183 |
| **Off** | Off | Off | **ON** | ON | ON | Off | **ON** | 184 |

| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | Address |
|---|---|---|---|---|---|---|---|---|
| **ON** | Off | Off | **ON** | **ON** | **ON** | Off | **ON** | 185 |
| Off | **ON** | Off | **ON** | **ON** | **ON** | Off | **ON** | 186 |
| **ON** | **ON** | Off | **ON** | **ON** | **ON** | Off | **ON** | 187 |
| Off | Off | **ON** | **ON** | **ON** | **ON** | Off | **ON** | 188 |
| **ON** | Off | **ON** | **ON** | **ON** | **ON** | Off | **ON** | 189 |
| Off | **ON** | **ON** | **ON** | **ON** | **ON** | Off | **ON** | 190 |
| **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | Off | **ON** | 191 |
| Off | Off | Off | Off | Off | Off | **ON** | **ON** | 192 |
| **ON** | Off | Off | Off | Off | Off | **ON** | **ON** | 193 |
| Off | **ON** | Off | Off | Off | Off | **ON** | **ON** | 194 |
| **ON** | **ON** | Off | Off | Off | Off | **ON** | **ON** | 195 |
| Off | Off | **ON** | Off | Off | Off | **ON** | **ON** | 196 |
| **ON** | Off | **ON** | Off | Off | Off | **ON** | **ON** | 197 |
| Off | **ON** | **ON** | Off | Off | Off | **ON** | **ON** | 198 |
| **ON** | **ON** | **ON** | Off | Off | Off | **ON** | **ON** | 199 |
| Off | Off | Off | **ON** | Off | Off | **ON** | **ON** | 200 |
| **ON** | Off | Off | **ON** | Off | Off | **ON** | **ON** | 201 |
| Off | **ON** | Off | **ON** | Off | Off | **ON** | **ON** | 202 |
| **ON** | **ON** | Off | **ON** | Off | Off | **ON** | **ON** | 203 |
| Off | Off | **ON** | **ON** | Off | Off | **ON** | **ON** | 204 |
| **ON** | Off | **ON** | **ON** | Off | Off | **ON** | **ON** | 205 |
| Off | **ON** | **ON** | **ON** | Off | Off | **ON** | **ON** | 206 |
| **ON** | **ON** | **ON** | **ON** | Off | Off | **ON** | **ON** | 207 |
| Off | Off | Off | Off | **ON** | Off | **ON** | **ON** | 208 |
| **ON** | Off | Off | Off | **ON** | Off | **ON** | **ON** | 209 |
| Off | **ON** | Off | Off | **ON** | Off | **ON** | **ON** | 210 |
| **ON** | **ON** | Off | Off | **ON** | Off | **ON** | **ON** | 211 |
| Off | Off | **ON** | Off | **ON** | Off | **ON** | **ON** | 212 |
| **ON** | Off | **ON** | Off | **ON** | Off | **ON** | **ON** | 213 |
| Off | **ON** | **ON** | Off | **ON** | Off | **ON** | **ON** | 214 |
| **ON** | **ON** | **ON** | Off | **ON** | Off | **ON** | **ON** | 215 |
| Off | Off | Off | **ON** | **ON** | Off | **ON** | **ON** | 216 |
| **ON** | Off | Off | **ON** | **ON** | Off | **ON** | **ON** | 217 |
| Off | **ON** | Off | **ON** | **ON** | Off | **ON** | **ON** | 218 |
| **ON** | **ON** | Off | **ON** | **ON** | Off | **ON** | **ON** | 219 |
| Off | Off | **ON** | **ON** | **ON** | Off | **ON** | **ON** | 220 |
| **ON** | Off | **ON** | **ON** | **ON** | Off | **ON** | **ON** | 221 |
| Off | **ON** | **ON** | **ON** | **ON** | Off | **ON** | **ON** | 222 |
| **ON** | **ON** | **ON** | **ON** | **ON** | Off | **ON** | **ON** | 223 |
| Off | Off | Off | Off | Off | **ON** | **ON** | **ON** | 224 |
| **ON** | Off | Off | Off | Off | **ON** | **ON** | **ON** | 225 |
| Off | **ON** | Off | Off | Off | **ON** | **ON** | **ON** | 226 |
| **ON** | **ON** | Off | Off | Off | **ON** | **ON** | **ON** | 227 |
| Off | Off | **ON** | Off | Off | **ON** | **ON** | **ON** | 228 |
| **ON** | Off | **ON** | Off | Off | **ON** | **ON** | **ON** | 229 |
| Off | **ON** | **ON** | Off | Off | **ON** | **ON** | **ON** | 230 |

| A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | Address |
|---|---|---|---|---|---|---|---|---|
| **ON** | **ON** | **ON** | Off | Off | **ON** | **ON** | **ON** | 231 |
| Off | Off | Off | **ON** | Off | **ON** | **ON** | **ON** | 232 |
| **ON** | Off | Off | **ON** | Off | **ON** | **ON** | **ON** | 233 |
| Off | **ON** | Off | **ON** | Off | **ON** | **ON** | **ON** | 234 |
| **ON** | **ON** | Off | **ON** | Off | **ON** | **ON** | **ON** | 235 |
| Off | Off | **ON** | **ON** | Off | **ON** | **ON** | **ON** | 236 |
| **ON** | Off | **ON** | **ON** | Off | **ON** | **ON** | **ON** | 237 |
| Off | **ON** | **ON** | **ON** | Off | **ON** | **ON** | **ON** | 238 |
| **ON** | **ON** | **ON** | **ON** | Off | **ON** | **ON** | **ON** | 239 |
| Off | Off | Off | Off | **ON** | **ON** | **ON** | **ON** | 240 |
| **ON** | Off | Off | Off | **ON** | **ON** | **ON** | **ON** | 241 |
| Off | **ON** | Off | Off | **ON** | **ON** | **ON** | **ON** | 242 |
| **ON** | **ON** | Off | Off | **ON** | **ON** | **ON** | **ON** | 243 |
| Off | Off | **ON** | Off | **ON** | **ON** | **ON** | **ON** | 244 |
| **ON** | Off | **ON** | Off | **ON** | **ON** | **ON** | **ON** | 245 |
| Off | **ON** | **ON** | Off | **ON** | **ON** | **ON** | **ON** | 246 |
| **ON** | **ON** | **ON** | Off | **ON** | **ON** | **ON** | **ON** | 247 |
| Off | Off | Off | **ON** | **ON** | **ON** | **ON** | **ON** | 248 |
| **ON** | Off | Off | **ON** | **ON** | **ON** | **ON** | **ON** | 249 |
| Off | **ON** | Off | **ON** | **ON** | **ON** | **ON** | **ON** | 250 |
| **ON** | **ON** | Off | **ON** | **ON** | **ON** | **ON** | **ON** | 251 |
| Off | Off | **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | 252 |
| **ON** | Off | **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | 253 |
| Off | **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | 254 |
| **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | **ON** | 255 |